Convention Number

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Electrical West

With which is consolidated the Journal of Electricity

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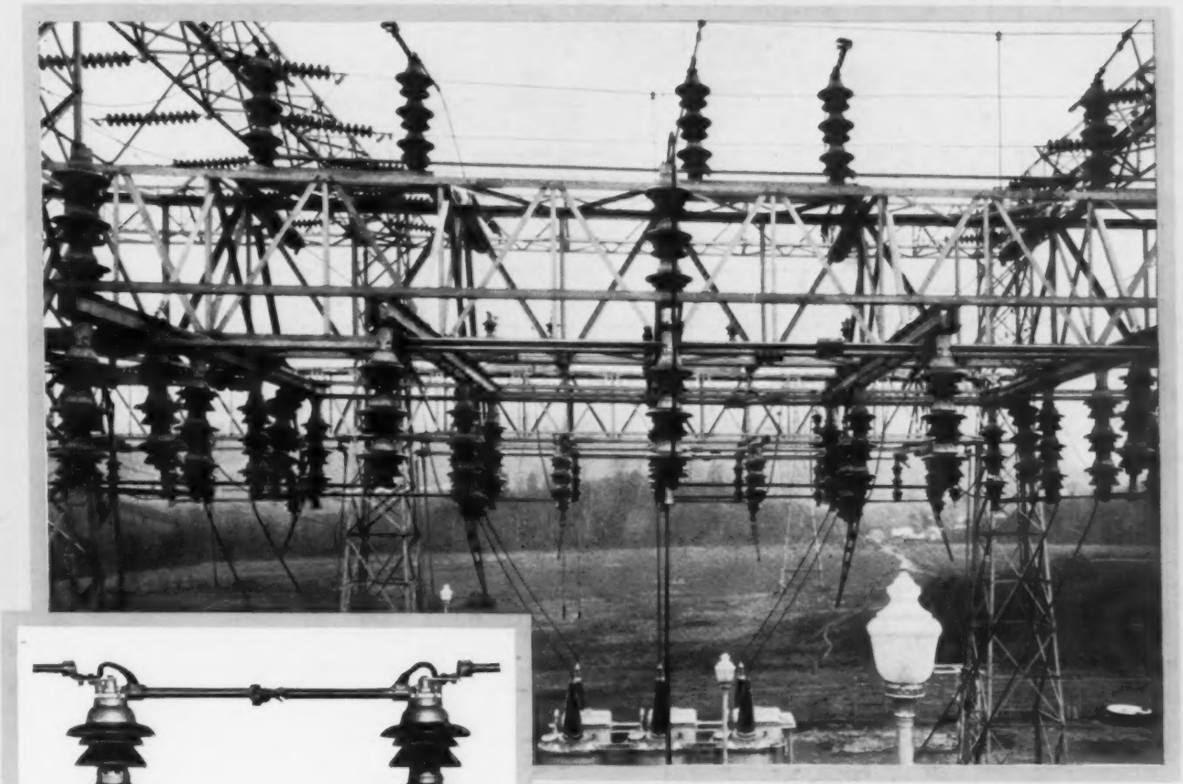

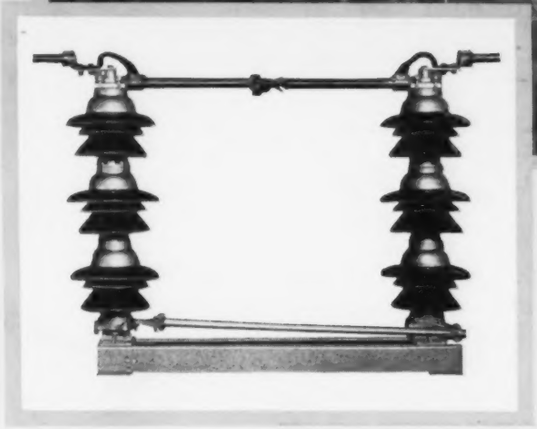

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With which is consolidated the Journal of Electricity

C. T. HUTCHINSON
Editorial Director

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G. C. TENNEY
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A Convention Between Two Covers

AS INDUSTRY becomes more and more complex, the need for trained men becomes greater and greater. Industrial organizations are using extraordinary efforts to induce their employees to learn, to train themselves. As their contribution to this program of industrial education, industrial publishers are bringing to their respective fields the best thought that the world has to offer for the guidance and education of their readers. Finally, industrial associations are providing the means for the compilation of the knowledge and experience of their members and the distribution of this material to the personnel for the benefit of everyone sufficiently interested to read and learn.

IN THIS last category rank the two organizations representing the combined forces of the electrical industry west of the Rocky Mountains. The Pacific Coast Electrical Association and the Northwest Electric Light and Power Association, through the scores of committees comprising the working membership, have furnished during the past year the machinery for the exchange of ideas and experiences of hundreds of employees.

CONTINUING the custom established some years ago, this issue of Electrical West presents the reports of these working committees. In bulk the work of the committees is impressive; in quality, originality of thought and in the advancement of ideas for the betterment of the affairs of the industry, this issue presents by far the best work the two associations have ever done. Commendation is due the eight hundred or more committeemen, who for a year have been engaged in careful study, research, analysis and discussion and have brought to final form the subject matter presented herein.

UNQUESTIONABLY the men engaged in this committee activity have benefited. But what of the two thousand other members of the associations who, through press of work, isolation or other cause, have not been able to do committee work? It is for them that the reports are published. To what extent these individuals capitalize on what this issue offers is for them to determine. Those who are mentally alert will use it as a stepping stone to progress; those who are mentally lazy will not.

ONE of these days executives who encourage their staffs to take part in the activities of associations such as those about to hold their annual conventions in Pasadena and Portland, will ask for a report of what has been learned by the members of their organizations. Each one of those who attend the conventions will be required to set forth the benefits derived by him. Each one who does not attend will be asked to summarize the committee reports pertinent to his particular field of endeavor. When such a course is followed the full benefits to be derived from the educational activities of the two associations will make themselves evident. The sheep will be segregated from the goats, the drones from the workers, and the wasters from the savers. In this way every member of the association will recognize his responsibility of taking from the association work something that will help him to do a better job for himself, his institution and the industry.

Where Two Annual Conventions Will Be Held

AT THE Huntington Hotel in Pasadena, Calif. (above), the Pacific Coast Electrical Association will hold its twelfth annual convention June 12-15, inclusive. This is the first time since 1920 that the association has met in Pasadena. The 1928 convention promises to be one of the most successful in the history of the organization. At the Multnomah Hotel in Portland, Ore. (below), members of the electrical industry from Utah, Idaho, Montana, Washington and Oregon will gather for the twenty-first annual convention of the Northwest Electric Light and Power Association June 19-22. These two Western conventions serve for the electrical industry of the West the same purpose as does the Atlantic City convention of the National Electric Light Association serve the industry in the Middle West and East.

Load Building Will Be P.C.E.A. Convention Theme

By W. L. Frost
President Pacific Coast Electrical Association.

INVENTORY time soon will be here. Each year, in June, the electrical industry of the Pacific Southwest meets in convention to report upon the progress that has been made during the past twelve months and to consider methods of handling those problems that will need attention in the future. It is to the great credit of the Pacific Coast Electrical Association that most of the accepted practices of our industry in the West have originated or have been improved through the work of the association either in convention or in the work of the committees.

We speak of public relations. Methods for meeting this problem have had their origin in a score of places, but without the work of the association in co-ordinating all the ideas brought forth by the various member companies, there could not be the comprehensive plan for public relations work that is being employed by all the companies today. An idea born in Chico will be found at work in El Centro; an advertisement first published in Fresno may be copied in Santa Ana; a lecture given in Los Angeles may be modified and used in San Francisco. There are no copyrights on such ideas when worked out in free co-operation.

One company builds a pipe line in a region which is subject to severe frosts, greater than any that the company has previously experienced. Through the association, the experiences of another company in similar circumstances are made available. A member company develops a plan for lessening vibration on transmission lines and all the facts immediately are at the disposal of all the other members through the work of the Engineering Section.

How do you figure mileage costs for trucks? How do you handle your insurance? What records do you use for emergency purchase orders? These are important questions and interesting questions such as men may discuss casually when they meet for lunch. They are studied carefully and answered thoroughly when brought before the Pacific Coast Electrical Association.

W. L. FROST

For the past two years the electric utility industry throughout the country has had its attention turned to load-building. Quite suddenly came the realization that the major problems of engineering and finance had been solved—that the next activity would be to get a greater earning out of the invested dollar—to get more kilowatt-hour sales from a given installed capacity. Ideas were advanced, some of them useful, others worthless, until we found ourselves in the widst of a mental fog.

The Pacific Coast Electrical Association determined to deal with these nebulae and crystalize them into a practical plan. During the year now closing this work has been carried on aggressively and the results will be reported at the annual convention to be held at Hotel Huntington in Pasadena, June 12 to 15.

While this study is of primary interest to the Commercial Section, it is realized that intelligent load building can be handled only through complete co-ordination of all branches of the business and accordingly each section has been asked to consider the subject from its individual viewpoint and to demonstrate how each department of the business as represented in each section can assist in the general plan of load building.

"Load-Building" will be the convention theme. Practically all of the items on the program will be animated to give a visual interest and to lessen the time of presentation. Six sections have made their plans for competing on Wednesday morning when the subject will be, "How can our section assist to stimulate load-building?" On Thursday morning the same sections will appear again at the general session to present the subject which the section considers of greatest interest to the industry. There will be seven general sessions all loaded with topics of great importance presented in attractive fashion.

It will be a good convention, well worth attending, and will be an inspiration to all members of the industry to carry on with renewed interest during the coming year.

Advertising-Publicity Section[1]

As a liaison group through which to further the efforts of other sections of the P.C.E.A. and of member companies in their public relations and commercial activities the Advertising-Publicity Section has had ample opportunity to demonstrate the purposes it set forth for itself in the Book of Standards it adopted in 1926. If its report in this instance is brief and seems to take to itself credit which is due to other sections for their achievements such is not the intention. The Advertising-Publicity Section is dedicated to serve usefully in conjunction with all other departments of the member companies. If it has been able to contribute in some measure to the success of these efforts that in itself is reward enough.

However, for purposes of record and to inform others interested in the extent of the section's activities during the past year such co-operative works should be described. This will constitute the first part of this report. The other portion of the report will condense into short space the important points discussed or demonstrated at its general meetings so that they may become working data for the guidance of members in their daily practice.

Co-operative Activities*

The information committee, functioning now for several years under the chairmanship of F. S. Myrtle, Pacific Gas and Electric Company, has been gaining in recognition as a reliable source of information on practically all matters dealing with public utility operation. "Requests for information on hydro-electric development in California come in from here and there," the chairman reported at one meeting, "and are met with reasonable promptitude." It was recommended, since a great number of inquiries come in from school teachers and students, that a circular letter be sent out to inform all schools of the service offered by the committee. This committee, functioning as a speakers' bureau made steps to supply speakers for meetings from locations in or near that from which the call was made.

The standards committee this year was not called upon to, nor did it initiate any revision of the Book of Standards as previously established, nor were there any requests made of it for decision as to qualifications of advertising media. Chairman A. C. Joy, San Joaquin Light and Power Corporation, reported that adherence to the present set-up of standards was proving effective. The establishment of these standards seems to have eliminated all doubt as to the type of media which is of value to power companies for their advertising and consequently less time at meetings is wasted in discussion of these questions, no mean achievement in itself.

The co-operative advertising committee, handling the section's work in connection with the California Electrical Bureau's state-wide magazine advertising campaign, was able to render advisory service both to the bureau and to the advertising agency handling the account. It was decided early to make use of copy released by the National Electric Light Association, revamped by the local committee so that it would more closely tie in with western methods. Also, it was decided to carry the line, "Electricity Is Cheap, Use More of It," which also would give it a tie-in with the 1927 load-building campaign enunciated as the prime purpose of the present administration. J. F. Pollard, Coast Valleys Gas & Electric Company, chairman, has followed this situation closely. It was further arranged this year to cause to be written a number of publicity articles, requested by the magazines in which the advertising appears, to tell of particular applications of electricity of particular interest to those served by the magazine in question.

The Lighting Bureau of the Commercial Section through its educational committee has given assistance in the preparation of dramatic photographs showing the effects of good and improper lighting upon children, for use in a statewide speaking contest before women's clubs and parent-teachers' organizations. These pictures were used in two ways: (1) greatly enlarged and mounted on cards and used when giving the lectures and (2) in the preparation of a direct-mail folder which was circulated by member companies to more than 1,000,000 residential lighting consumers. Working with Clark Baker, chairman of this activity for the Commercial Section, was W. A. Cyr, Electrical West. The effectiveness of this educational promotional activity has been demonstrated to be cumulative and may be expected to bring more and more results each year as the activity is continued. In this campaign of lighting education the merest start was made. The report of Mr. Baker's committee, to be found among the Commercial Section lighting bureau papers in these proceedings, shows, however, that the start itself is a considerable achievement in promotional activity.

For the interchange of advertising ideas a new committee was formed this year, headed by Forrest Raymond, San Diego Consolidated Gas and Electric Company, which gathers together copies of advertising of member companies and then redistributes them to others in the section for their information.

Convention Advisory Board

Due no doubt to the successful way in which was conducted the 3-minute speaking contest at the convention last year when he was chairman of the Advertising-Publicity Section and responsible for that feature of the program, Richard E. Smith, Southern California Edison Company, was appointed general convention chairman for this year's convention by President W. L. Frost. In a letter to this section read at its first meeting Mr. Frost asked the co-operation of this section in preparing an unusual program for the convention.

The first steps taken by Mr. Smith to make the convention an entirely original one in every respect were announced at the section meeting, Sept. 21. It was proposed to (1) have all routine matters disposed of in section meetings during the year; (2) have the program planned immediately, the section program committee to design their part in it early; (3) have the entire convention program "animated" or dramatized by the use of slides, moving pictures, plays, diagrams or other methods of making graphic the message presented.

It was asked that the Advertising-Publicity Section act as an advisory body to the convention chairman and work to create a complete and unified program of convention activities.

The Advertising-Publicity Section again was asked to take charge of the 3-minute speaking contest to be conducted as an elimination contest by each member company under the arrangements made by the section member in that company. The winners of the elimination contests will be given a final contest at the noon luncheon, Tuesday, of the convention. Dan L. Scott, Los Angeles Gas & Electric Corporation, was named to have charge of the arrangements for this contest. The subject of the talks is to be that of the section's advertising slogan, "Electricity Is Cheap —Use More of It."

From the tentative outline of the convention program as prepared by Mr. Smith there is every reason to believe that it will be one of the most unusual conventions ever held by the association. A number of departures from the traditional procedure are planned and an entirely new trend in conventions should result from its original features.

The elimination of long routine reports, limiting the parallel sessions of sections to one morning's business session, promises to set a popular model for future conventions. The contest between the sections, each presenting a dramatized program to demonstrate what that section can do in the promotion of load building and competing for a substantial prize, no-

[1] **J. C. Jordan,** Pacific Gas and Electric Company, chairman. **A. C. Joy,** San Joaquin Light & Power Corporation, vice-chairman. **E. P. Ramsay,** Los Angeles Gas and Electric Corporation, secretary. **Coast Valleys Gas & Electric Company:** J. F. Pollard. **Electrical West:** Wm. A. Syr, G. C. Tenney. **Los Angeles Gas and Electric Corporation:** D. L. Scott. **Pacific Coast Electrical Association:** S. H. Taylor. **Pacific Gas and Electric Company:** F. S. Myrtle. **San Diego Consolidated Gas & Electric Company:** F. M. Raymond. **San Joaquin Light & Power Corporation:** S. W. Green. **Southern California Edison Company:** W. L. Frost, R. G. Kenyon, R. E. Smith. **The Southern Sierras Power Company:** F. Z. Stone. **Westinghouse Electric & Manufacturing Company:** F. L. Tainter.

* Report of Business Activities.

ticeably enlivened interest in the convention and each section has been busy with preparations. Changes in the conventional groupings of open meetings, the elimination of the banquet, and other similar changes all portend a radically different convention this year.

Improvement of Technique*

The afternoon session of each section meeting of the Advertising-Publicity Section is devoted to a symposium on some subject of particular value to the advertising or publicity work of members and is open to anyone else interested in the subject.

Radio Advertising was the subject of discussion at the first section meeting, Sept. 21, 1927. The program was in charge of R. G. Kenyon, Southern California Edison Company. Carl Havelin, commercial manager of radio station KFI, Los Angeles, was the speaker.

Mr. Havelin brought out the point that radio advertising does not claim to sell directly, but effects sales indirectly as a result of good will established for the company broadcasting. It does, however, put the advertiser in direct communication with people in their homes and offers an enormous prospect list reached at their lowest resistance point. He substantiated this point with the estimates made by the National Broadcasting Company of approximately 300,000 radio sets in and around Los Angeles and 250,000 sets in and around San Francisco with an average of 4.7 people per set.

Mr. Havelin said that he believed radio offered utilities a fine means of building good will and at relatively low cost. He told of the New York Edison Company which now is expending about $50,000 a year on radio good-will building and finding it most successful. He also told of the experiences of the Standard Oil Company and the California Petroleum Corporation in using radio. These firms both sponsored high-class programs such as symphony orchestra concerts and the opera, and as a direct result distributed hundreds of thousands of booklets by direct request as well as increased their sales. A brief talk by Frank Hobart, advertising manager of the California Petroleum Corporation, bore out Mr. Havelin's remarks and testified to the value to his company of its radio advertising experience.

In open discussion which followed answers to particular questions resulted in the obtaining of such additional information.

Electrical Merchandising Advertising was the subject of the next meeting, Nov. 18, 1928, held jointly with the Commercial Section at San Francisco. A. C. Joy, representing the Advertising-Publicity Section, presided over the joint meetinig.

Richard Neustadt, managing director, Retail Merchants Association of San Francisco, was the feature speaker provided by the Advertising- Publicity Section. His talk proved devastating to self-complacency, for he brought charges against central-station merchandising and advertising. These charges were: cockiness in attitude toward small merchants and merchandising because of a heritage from an engineering and financial frame of mind in early utility development; conceit in that when merchandising was undertaken by power companies it was too often taken for granted that people would buy appliances just because the power companies were selling them and that therefore no real s e l l i n g or advertising effort was needed; and ignorance in that selling methods had been used which were totally disregarding and were evidently in complete ignorance of well established principles of sound merchandising.

He told of his own experiences, when his house was burnt out recently and he planned to rebuild. He described the quantities of literature and sales letters urging him to use all kinds of building materials, household equipment, etc. but not a single circular on any electrical apparatus, wiring, equipment. "No one is really selling electrical appliances, not even the electrical industry," he said, and declared the idea that the problem was a unique one was untrue, that it was unique only because of the present attitude toward it. He warned that unless all outlets for merchandising were developed and organized, electrical appliances would be left out of the picture by more aggressive sellers of merchandise in other lines.

"If you could get a monopoly on electrical appliances, and you can if you take all the profit out of them for other dealers by your terms and prices and premiums, you won't sell half the number of appliances that you do today," he said, pointing out the experiences of other lines which had striven to get along without the small retail dealers in their distribution schemes. He urged the taking into the fold of the electragist, the small merchant and the department store and have them all w o r k for the industry.

While not on the Advertising-Publicity Section program for that day Miss Clotilde Grunsky, Pacific Coast Editor of Electrical Merchandising, in her talk on a woman's viewpoint of electrical merchandise brought out some factors in respect to appliance advertising which it will be well to record in these proceedings.

She criticised advertising designed to reach the housewife and which was written sentimentally. While the housewife may not be interested in reading a technical description of the mechanics of a refrigerator she will be interested in a description of its usefulness to her written in the technical language applicable to her domestic routine. That is to say, the housewife regards housework not in the least poetically as some advertising would make it seem, but as the technical side of her home. To address her, advertising must know that technical language and approach her from that angle.

Fancy writing and writing "down" to the housewife is not appreciated, she pointed out. The housewife is intelligent and alert to detect misleading statements or statements designed to make it appear that housework may become a dream by means of electrical equipment. Miss Grunsky also said that radio has been overlooked as a means of carrying truly worthwhile information to the housewife during the day.

Newspaper Advertising for Public Utilities, the subject of the afternoon meeting of the March 9, 1928, section meeting, was an informal one devoted largely to an interchange of experiences.

Don Francisco of the national agency of Lord & Thomas and Logan talked informally and a lively discussion, answering questions and outlining the present advertising programs of the various companies, followed.

Direct-Mail Advertising was the subject under study at the May 4, 1928, meeting of the section, held in conjunction with the All-Western Direct-Mail Advertising Convention and Exposition, at the Exposition Auditorium, San Francisco. A visit to the advertising exhibit in the afternoon to study the types of utility direct-mail literature displayed there took the place of a formal program. A number of the section members took advantage of the full 3-day program of the convetion. J. C. Jordan and W. A. Cyr were in charge of the arrangements for this meeting.

Section Convention Program at Pasadena

Upon A. C. Joy rested the largest responsibility in connection with the Section's program at the convention in Pasadena. He was named as chairman of a committee to prepare a moving picture film showing how the section can assist in load building. He was also asked to prepare the talk for the Thursday morning session on the subject of what the section believes is of the most importance and greatest interest to the entire convention. This is to be in the nature of an animated discussion of the development of the state, the problems of its industries and the part of the electrical industry in this work.

To Mr. Joy also was given the responsibility for writing a humorous playlet to be presented as an opener for the last business session of the convention.

Extension of Work for Other Sections.

As expressed in its Book of Standards the Advertising-Publicity Section has made itself available to other sections or committees of the association for particular study or action on any problems which they may have involving advertising or publicity efforts. During the past year this work has been extended in a number of fields, but the section stands ready for still greater usefulness in this respect and invites other sections to make their requests known.

There is growing inter-relation between the various branches of the industry and between the various departments in the individual companies. In a great many instances, in fact in practically all instances, the interpretation of one group or branch or department to its fellows in order that its activities may be

* Report of Educational Activities.

carried through with the united support of all other related parts involves publicity or the spread of information. In these endeavors the section will be glad to work.

Particularly in the commercial and public relations departments is closer liaison desirable. As the intermediate group the Advertising-Publicity Section invites more opportunities to serve in these capacities.

Commercial Section

Executive Committee Report[1]

Speeding up of the year's work was possible because of the "continuity" organization plan adopted by the section last year.

The first organization meeting was held during the Santa Cruz convention. At this session all of the major that were to be held during the administrative year. There can be no doubt as to the effectiveness of the organization plan, for at the September conclave, held in Los Angeles, every committee was organized and actively engaged with constructive discussion of its problems.

The section chairman wants to take this opportunity to thank the executives of all member companies of the P.C.E.A. for their whole-hearted co-operation. At the outset of the year all companies were addressed a letter in which was outlined the year's program and then asked to nominate the personnel of their respective companies who would be permitted to serve on committee and attend conclaves. The repose to this letter was very gratifying and the committee delegation very generous.

Attendance at conclaves and committee action are the vehicles of a successful Commercial Section, and all these were in constant evidence throughout the year. Conclave attendance was: Los Angeles, September, 175; San Francisco, November, 140; Fresno, March, 120.

President Frost aptly stated that the "commercial era" had arrived and adopted as his slogan "a united industry." With these facts the commercial men were eager to delve into all the problems of load building—at the same time giving due regard to trade and public relations.

At each conclave a definite theme was presented, all of which were aimed to broaden the commercial men and stimulate load-building activity. Non-essentials were eliminated and only those subjects calculated to reflect their results in the balance sheet were considered.

For the September conclave the "commercial era" theme was adopted. During the year there took place a decided revival of interest in load-building by all central stations in the P.C.E.A. group and the section was particularly fortunate in having as its speakers such men as R. H. Ballard, president, and F. B. Lewis, assistant general manager of the Southern California Edison Company; Judge Appleton, vice-president of the General Electric Company, New York, and Elliot Hensel, advertising manager of the Los Angeles Illustrated News. If there was any doubt in the minds of anyone attending the conclave it was definitely set aside by the forceful manner in which Mr. Ballard discussed the need of load-building. Mr. Lewis added emphasis to the theme and proved to the satisfaction of all commercial men that their day had arrived.

Mr. Ballard in his analytical presentation of the need for load-building referred particularly to the domestic kw.-hr. consumption of his company, which stood at approximately 500 kw.-hr. and raised the mark to be realized the next four years to 1,200 kw-hr. He also pointed out that all the financial and engineering problems of the industry had been solved and now executives were to bend their talents and efforts to load-building.

Mr. Lewis explained that plants had been developed, transmission and distribution facilities had been expanded. With such a plant he likened the industry to the human body—the plants and transmission lines being the brains and spinal column and the distribution network the ribs, so that now it was necessary for the commercial men to develop the body.

Judge Appleton, who kindly came all the way from New York to address the section, provided a fund of ways and means of load-building. He gave a picture of what was being done elsewhere by the industry and suggested many possibilities of increasing the use of electricity.

Mr. Hensel closed the session with his talk on the "three G's of selling"; in brief these were "guts," "glee" and "glue."

The November conclave theme was built around the thought of how to do the job that was placed squarely before the commercial men. At this meeting the section was favored by an interesting talk by President Frost on his views on "commercial development." Committee action occupied the greater part of the two days conclave and of the afternoon of the last day the Advertising and Publicity Section of the P.C.E.A. joined forces with the Commercial Section. This program had such headliners as Richard Neustadt, managing director, Retail Merchants Association of San Francisco, who dealt with electrical merchandise advertising, Clotilde Grunsky, Pacific Coast editor, Electrical Merchandising, who very pertinently presented "appliance merchandising from the standpoint of the housewife," and Lewis A. McArthur, vice-president and general manager, Pacific Power & Light Company, Portland, Ore., gave an instructive talk on "practice what you preach."

The March conclave was an open forum where for two days each bureau presented to the entire section those matters considered of importance and interest to all. It is impossible for every member to participate in all committee discussions and as each committee presented before the entire body its activity there was some very interesting discussion. The lighting bureau presented for the benefit of the section the lecture and demonstration that was delivered throughout the entire state before parent teachers' associations and women's clubs, as well as many commercial organizations. The commercial lighting committee also displayed the demonstration used to obtain the co-operation of merchants for the purpose of selling better store lighting. Chairman Graef, of the general bureau, presented an interesting outline of the customer relations essay contest that is being conducted. The results of this activity will be presented to the June convention. Customer relations is a subject of much importance that must not be neglected, for when building our business we must be certain that we are likewise building good will. The power and heating bureau presented its work of assembling information for the agricultural handbook. The merchandise bureau activities were interesting, especially its work towards adopting a uniform and minimum wiring standard. The range committee offered a motion that the P.C.E.A. join the California Association of Electrical Inspectors in an effort to obtain a simplified range wiring plan and specifications. The P.C.E.A. appointed the following men: H. C. Rice, Southern California Edison Company; W. F. Nieman, Pacific Gas and Electric Company; and C. J. Geisbush, California Electragists, as a committee to confer with the inspectors who were meeting in convention at Santa Barbara. As a result of this meeting specifications and plans were agreed upon and were sent to the Board of Fire Underwriters for final approval. Until this approval has been obtained they cannot be released officially.

The Commercial Section also adopted the following

[1] Executive Committee—**W. C. McWhinney,** Southern California Edison Company, chairman; **J. F. Pollard,** Pacific Gas and Electric Company, vice-chairman; **H. K. Griffin,** California Water Service Corporation, ex-officio. **G. T. Bigelow,** The Southern Sierras Power Company; **R. L. Cardiff,** Coast Counties Gas & Electric Company; **G. H. P. Dellman,** San Diego Consolidated Gas & Electric Company; **A. M. Frost,** San Joaquin Light & Power Corporation; **C. J. Geisbush,** California Electragists; **W. P. Graef,** Southern California Edison Company; **J. H. Jamieson,** Westinghouse Electric & Manufacturing Company; **A. H. Nicoll,** Graybar Electric Company; **E. F. Perkins,** Pacific Gas and Electric Company; **G. D. Smith,** Ontario Power Company; **G. C. Tenney,** Electrical West; **J. W. Wrenn,** Great Western Power Company.

resolution which was addressed to the executive directors of the association:

Recommendations of the General Merchandising Committee Relative to Power Company Merchandising.

Since the foregoing principles for the promotion of electric appliances have been defined and agreed upon by accredited representatives of the independent trades in joint conference with accredited representatives of the National Electric Light Association, and

Since it is consistent with the power company interests in marketing its product—kilowatt-hours—to encourage all established outlets engaged in the sale of electric merchandise,

The merchandising committee of the National Electric Light Association, realizing the desire of the power companies for constructive competition in the merchandising field, recommends the following principles governing merchandising practice, supplemental to the general principles agreed upon by the joint trades conference.

1. Price cutting on "standard" lines of electric devices, directly or indirectly, or the sale of other electric lines at margins incommensurate with the cost of selling, except for sound merchandising reasons, brings loss in operations which is not conducive to constructive building in the electric appliance merchandising field.

2. When combination sales are advisable, adequate margins should govern selling prices. Only the "true value" of acticles should be stated in advertising. Nothing constructive is gained through exaggerated statements of "values."

3. Deferred payments in connection with the sale of all merchandise is universal practice. The practice is accepted by sound financial authority and favored by the public. Its abuse we would strongly discourage.

It is recommended that a period of not exceeding eighteen months be the maximum time allowance for load-building devices in the pioneering stage; that a period not exceeding fifteen months be extended for financing motor-driven devices having general public acceptance; and that relatively shorter terms, on a self-supporting basis, be extended on items selling for less than $25. A carrying charge for financing service should be made in all cases, and an initial payment should be required large enough to constitute a sale.

4. The power company is in the merchandising business for the promotion of devices which constitute a medium of electric service. There are kindred lines to merchandise which are naturally used in conjunction with the appliances, but we suggest it is not desirable for the merchandising department of the power company to engage generally in the direct sale of non-electric devices.

5. We recommend a complete classification of merchandising accounts by our association.

Pacific Coast Electrical Association Commercial Section.
By W. C. McWHINNEY, Chairman.

General Bureau Reports

Customer Relations*

The customer relations committee repeated the essay contest which has been held during the past several years.

Twenty thousand booklets entitled "Employee and Customer" which set forth the essential factors in the promotion of better customer relations, were supplied for the use of employees of all member companies. Employees were requested to read the booklet thoroughly and then put in writing what they consider to be its three outstanding features and giving their reasons for same.

Recognizing the great importance of the proper treatment of our consumers and to further better public relations, the association, through its customer relations committee offered liberal prizes for the winning papers, as follows:

First prize, $150.
Second prize, $100.
Third prize, $75.
Fourth prize, $50.
Next five prizes, each $25.
Next ten prizes, each $15.
Thirty prizes of $5 each will be awarded by a drawing.
The rules of the contest were as follows:

Contest Opens—April 5.
And Closes—May 1.

1. Read and familiarize yourself with the text.
2. Select three outstanding points in the relationship between the public utility employee and the consumer as covered by the text (e.g. Courtesy, Frankness, etc.).
3. Discuss each of your three points as to:
   a. Reasons for relative importance.
   b. Give a specific example from your experience in illustration of the working of the relationship and how it benefits the company.
4. Limit paper to 1,000 words.
5. Submit your paper to your company contest director on or before May 1.
6. Your paper must be unsigned. In order to identify it, include with it a sealed envelope containing your name and company. Paper will be assigned a number by the contest committee for identification.

While the 1927 contest was a most successful one from the standpoint of number of papers submitted, showing a total of 1,007, it is expected that the result of this year's contest will greatly exceed that figure. One of the most gratifying results of the contest of last year was the fact that approximately 50 per cent of the essays were written by employees in the operating departments of the various member companies.

* Report of customer relations committee of the general bureau of the Commercial Section. W. P. Graef ,chairman: W. P. Schafer, vice-chairman. O. A. Brugier, A. G. Cage, R. C. Hanna, Lloyd Henley, Alfred May, O. L. Moore, M. McNeil, D. L. Scott, R. T. Stephens, F. C. Todt, F. H. Woodward, J. W. Wrenn.

Lighting Bureau Reports[2]

Bureau Activities

The lighting committee this year consisted of the following five subcommittees:

Educational—Clark Baker, Sr., chairman.
Commercial Lighting—Victor W. Hartley, chairman.
Sign and Flood Lighting—H. H. Robison, chairman.
Campaign—C. D. Monteith, chairman.
Street and Highway—R. R. Walbridge, chairman.

Educational

The educational subcommittee carried on very constructive work in the form of lectures and in the circulation of a bill stuffer. There were more than one million of these furnished to member companies for distribution and the committee hopes that good use has been made of them.

Sixty-one lectures on the "Story of Artificial Light" were given to approximately 7,000 business men throughout the state. These talks have been helpful, both from the standpoint of public relations and their definite commercial value. These talks were given mostly by member company employees.

A talk was designed with illustrations to be presented before parent-teachers' associations and women's clubs throughout the state. This was called "How We See and Why We See" and dealt with lighting in the home and lighting in the school, with a motive of conservation of vision during school life.

This was presented to approximately 6,000 women in the various parent-teachers' associations and women's clubs. Undoubtedly, this number is small when compared to the total of these organizations, but it is hoped that the incoming committee will carry on this program, as the interest in this subject has just been aroused by these talks.

Dr. Mariana Bertola of the Women's Federation

[2] **G. H. P. Dellman,** San Diego Consolidated Gas & Electric Company, chairman. **California Electrical Bureau:** V. W. Hartley. **Coast Counties Gas & Electric Company:** R. L. Cardiff, M. L. Foster, P. S. George. **Edison Lamp Works:** L. G. Gianini, R. V. Ludlum. **The Electric Corporation:** G. A. Anderson, F. A. Hansen. **Electrical West:** Wm. A. Cyr. **Fobes Supply Company:** R. F. McDonald. **General Electric Company:** S. E. Gates, Carl Koch, E. P. Markee, H. B. May. **Graham-Reynolds Electric Company:** Lee Oakford. **Graybar Electric Company:** F. N. Cooley, H. L. Harper, A. H. Nicoll. **Great Western Power Company:** H. E. Brillhart, F. S. Curran, Stanley Walter, J. W. Wrenn. **Edwin F. Guth Company:** L. A. Hobbs. **Illinois Electric Company:** D. C. Pence. **Los Angeles Bureau of Power and Light:** F. D. McKinstry. **Los Angeles Gas and Electric Corporation:** L. J. Gilmeister, Frank Weiss. **Marbelite Corporation of America:** W. J. Fritz. **The Miller Company:** J. H. Maddox. **National Lamp Works:** Clark Baker, H. C. Falkell, C. P. Wallis, Roy Palmer, William Ross. **Pacific Gas and Electric Company:** W. S. Hanbridge, C. D. Monteith, Gardner Buss, L. F. Galbraith, H. L. Jackman, G. N. Rooker, J. S. C. Ross, W. C. Schafer, A. A. White, H. S. Robison. **Pacific States Electric Company:** E. W. Garcia, F. E. Carew, F. B. Nightingale, F. Van Gilluwe. **Reiman Wholesale Electric Company:** S. W. Messick **San Joaquin Light & Power Corporation:** H. H. Courtright, M. P. Lohse, A. R. Theils, P. B. Wilson. **Southern California Edison Company:** W. G. Blossom, W. L. Deimling, W. P. Graef, C. E. Hewes, C. E. Houston, H. J. Moulton, W. C. McWhinney, Fred Schwartz, R. Walbridge, A. I. Whitehead, H. S. Williamson, A. B. Wollaber. **The Southern Sierras Power Company:** G. T. Bigelow, W. R. Chawner. **Vallejo Electric Light & Power Company:** Edwin Pierce. **H. H. Walker Company:** H. H. Walker. **Western Light & Fixture Company:** J. L. Kline. **Westinghouse Lamp Company:** R. F. Conlisk, B. R. Deleray, C. E. Johnson, R. S. Prussia.

Congress has sent a general letter to all of the women's clubs affiliated with the federation, asking them to schedule this talk. It is also suggested that the incoming committee immediately get in touch with the various parent-teachers' clubs and schedule this talk before these groups during the coming year.

This subcommittee also carried on a lighting school at Santa Cruz with very good results.

Commercial Lighting

This subcommittee has undertaken to establish four ideally lighted commercial establishments in Sacramento, San Francisco, Long Beach and San Diego. It has chosen four types of stores and is meeting with considerable success in this work. The committee assists in the relighting of these stores, so far as expense is concerned, therefore is very definitely able to control the exact type of illumination.

This committee's work is not yet completed and no definite data will be available until the June convention. In fact, this work should be carried on by the incoming committee.

Sign and Flood Lighting

This subcommittee has made an extensive survey of the possibilÄies in sign and flood lighting, taking into consideration the new type of sign lighting and also suggesting further ways and means of building load with flood lighting. This report should be available to those particularly interested by June 1, 1928.

Campaign

This committee has made a study of lighting campaigns, refixturing campaigns with suggestions for the carrying on of future campaigns.

While this type of work has been new to the lighting committee, very fine progress has been made. A questionnaire has been prepared and sent to the various member companies on the Pacific Coast and some very interesting data have been secured.

This committee's work is not yet fully completed but full reports will be available at a later date.

Street & Highway Lighting

This committee, in following up that of last year, has made a definite recommendation, giving cost data, etc., to the California Highway Commission on the lighting of main highways in California, and it is hoped that the incoming committee will continue this work so that we may soon have proper and adequate highway lighting on at least the main arteries in the near future.

Commercial Lighting*

Just how many more people will a well-lighted store-window stop than a window with inadequate or improperly planned illumination? To just what added extent are people inclined to linger shopping, and consequently purchasing, in a store illuminated so that it has a pleasing atmosphere than they are under conditions of gloom or glare?

These two questions summarize the problem which the commercial lighting committee of the P.C.E.A. set out to solve this year with the hope that in acquiring the necessary data they would also stimulate a general interest in better illumination among all merchants; and would establish a concrete instance upon the records of each power company whereby it could be determined just to what degree it would be profitable to the companies to go out after a better general standard of commercial illumination.

Four cities, spread widely over the state, were selected for the test cases and a local committee was placed in charge of the activity in each. The plan agreed upon involved the complete remodeling and modernizing of the lighting installation in one store in each city. As soon as the test store was determined upon a check was to be made of the number of people passing and the percentage who stopped to look into the windows. Then when the change was effected the check was to be repeated. At the time of the second check a similar check was to be made upon a store of the same type in the same neighborhood, as a counter-check to offset any effect from weather conditions or other variable factors.

As a check on the increased revenue due to improved lighting conditions in the store interior the merchants were to provide data from which a curve could be plotted showing the monthly trend of their business for a period of twelve months immediately prior to the alterations. Similar information from month to month after the change would enable superimposing a curve of the current year's business upon that of the previous year.

In order to obtain a broader scope of interest in the test than would normally be taken in such an experiment confined to one merchant's establishment, it was decided to enlist the support of the local advertising clubs and retail merchants associations by taking the program before their boards of directors, asking their help in selecting the test store and obtaining the privilege of rendering progress reports at their meetings during the test period. In this way every merchant member of these clubs and associations would have the matter kept constantly before him and would, at the close of the test, be fully informed of the results.

By making these alterations in an already existing store the power companies upon whose lines they were located would have a definite example of the increased revenue to be derived through selling better illumination to their commercial customers and could determine the exact value of comprehensive commercial lighting campaigns.

The four local committees had a big job cut out for them and a comparatively short time in which to bring their work to a conclusion; so, as a means of stimulating the immediate interest of the merchants and making them anxious to participate in the activity rather than procrastinating in their decision, a budget of $1,200 was prepared to provide a sum of $300 which each committee could offer to the merchant accepting the proposal, to apply toward the cost of the alterations.

The budget was approved by the executive committee and with the foregoing picture before them the committees proceeded with their work, each independent of the others.

Progress to Date

In every case the repection given the plan by the merchants was greater than had been expected or hoped for.

The San Diego Advertising Club readily expressed an approval of the plan and a desire to aid in its execution. The Long Beach Advertising Club not only gave its approval but wrote to the Long Beach chairman endorsing the plan and extending every facility toward aiding in its successful execution. The Sacramento Advertising Club devoted the program of one meeting to the outlining of the plan and extended a special invitation by letter to every merchant who is not a member of the club to attend on that day. The San Francisco Retail Merchants Association invited the state chairman and the San Francisco chairman to present the plan at a meeting of the board of directors. This board is made up of one representative of each type of retailing business in San Francisco, and the meeting was very successful. There was a very general discussion of lighting and its effect upon merchandising which in itself was well worth while. It was most encouraging to see fifteen of the leading merchants of San Francisco spend a half hour discussing light and its influence upon their businesses.

When the committees set out to select their "test stores" they each soon found one very interesting fact —a far better job has been done in selling to the merchants the real need of good illumination than has been realized. That this realization of need has not resulted in better lighting jobs is due to the fact that most of the commercial buildings are not wired to provide the proper capacity necessary for good nated that it offeredrb the
lighting. Practically every store that was so poorly illuminated that it offered itself as suitable for a test such as it was desired to make was already lighted to the fullest possible extent of its copper capacity and the merchant was well aware of his deficiency but due to a short-term lease or a soon-expiring lease was loath to go to the expense of rewiring the entire building.

It soon became apparent that the real task for the committees was to make the test cases outstanding examples of the improved general atmosphere in well-lighted stores and thus bring lighting and its importance in merchandising so forcibly to the attention of the merchrants that on renewing leases or moving to

* Report of subcommittee of the lighting bureau. V. W. Hartley, chairman. E. Brillhart, G. H. P. Dellman, W. P. Graef, W. S. Hanbridge, M. C. Pfyl, P. B. Wilson.

new locations they would give prime consideration to lighting conditions and demand an installation which would permit them to use light properly and to the best advantage.

The final selections were: In Long Beach, a jewelry store; in San Diego, a shoe store; in San Francisco, a combination confectionery and restaurant; and in Sacramento, a haberdashery.

The San Diego test is of particular interest. The store is located one block off the main thoroughfare of the city and although the street is occupied by stores carrying a good quality of merchandise it enjoys little or no night traffic. The daytime traffic on this street is 80 per cent as great as that on the main thoroughfare, the night traffic is only 2 per cent. The street is dark and uninviting at night and, because of the small amount of traffic, the merchants use their window lights very little. By installing one good window lighting job and encouraging the merchant to make good use of it it is expected that the surrounding merchants may be similarly encouraged and with this general brightening up of the district the city authorities are to be requested to improve the street lighting. Thus it is hoped to show that the shopping district of a community can be enlarged through the proper use of light.

That this is not an exaggerated hope is clearly evident from the fact that since the Pacific Gas and Electric Company and the Great Western Power Company have installed high intensity window lighting in their offices, which are located on the same block in San Francisco, the night traffic on that block has increased by several hundred per cent. It is also significant that the traffic on the opposite side of the street is less than it was formerly. Unfortunately these offices are not located in a retail shopping district, therefore no check can be made of increased sales due to the additional traffic brought to the neighborhood.

Working independently of each other the committees have reached various stages of progress in their tests at the time of writing. Long Beach has already reached the point where the tangible results begin to show—here the revised installation has been completed. The changes effected were as follows:

Windows: Six 200-watt units with reflectors unsuited for the purpose were replaced with sixteen 150-watt units of correct design, and two duplex convenience outlets were installed for decorative lamps.

Store Interior: Three 300-watt units were replaced with nine 200-watt units; 350 watts were added to the work-room; a 50-watt desk lamp was installed in the small office; and six duplex convenience outlets were installed throughout the store for decorative lamps.

Sufficient time has not elapsed for the acquirement of the desired figures regarding the effect of this alteration upon the business but the committee is engaged in procuring them at the present time; and the satisfaction of the merchant is clearly expressed in his letter which accompanies this report. Another letter is also printed as it was written by a merchant who was approached at the same time and also revised his lighting according to the recommendations of the committee. These two letters clearly evidence one result of the work beyond that originally anticipated—they show an appreciation by the merchants of the willingness of the power companies to aid them in their merchandising problems that has a very definite public relations advantage.

Conclusions and Recommendations

The obvious conclusion resulting from the committee's activities is that the commercial lighting campaigns of the past have borne greater fruit than has heretofore been realized, that a very satisfactory job has been done in convincing merchants generally that a window without proper illumination is a mere storeroom for merchandise whereas, well lighted, it can be made a very powerful salesman, and that a store interior must be bright and cheery yet free from glare if customers are expected to return. At the present time, however, the electrical industry cannot harvest the fruit which it has nurtured because of the lack of copper capacity whereby the merchant can be given the lighting which he needs and wants.

The problem resolves itself, therefore, into a matter of adequate wiring in commercial structures to meet the present-day needs of the merchant occupants and whereas it would require a most extensive campaign, and one whose results would be questionable, to promote the idea of rewiring the already existing stores, unless we desire to face similar obstacles for years to come, even in the new structures to be built, a definite campaign should be planned to bring the importance of the electrical layout to the attention of architects, builders and engineers who are responsible for drafting the plans of commercial buildings.

Therefore, it is the recommendation of the retiring commercial lighting committee that the incoming committee give its attention to the possibility of establishing a set of adequate wiring standards for commercial structures similar to the Red Seal standards for residence wiring, and like them to be actively fostered to the end that commercial lighting needs may be properly served and the electrical industry may get its full share of the returns from this most profitable source of revenue.

Letters commenting upon the work of the committee in Long Beach Follow:

BOYSON JEWELRY COMPANY
Diamonds, Watches, Silverware
243 Pine Avenue
Long Beach, California,

March 17, 1928.

Pacific Coast Electrical Assn.,
Care W. P. Graef,
Long Beach, Calif.
Gentlemen:

We wish to advise you that the work of installing the entire new lighting system of our store has just been completed.

We are very much pleased by the manner in which the work was carried on, the men being very courteous and considerate in every way, thus making it possible for their work to continue without interfering with our business any more than was absolutely necessary. They worked as late as 3 o'clock in the morning and they did it with a smile.

The new lighting of the store is wonderful. We would not have believed there could be such a difference in the general appearance of the store. We have not had it installed long enough to tell how it will affect business, but we will gladly advise you later as to the results.

Mr. Claude Lindsey of the Southern California Edison Company has spent a great deal of his time on this installation, seeing to it that every little detail was worked out just right. We feel that a lot of credit is due him for this being strictly a perfectly lighted store.

We appreciate very much your selection of our store for this contest, giving us the opportunity of having the change made. We want to thank you also for sharing the expense. Any time we can be of service to you please feel free to command.

Yours truly,

BOYSON JEWELRY CO.
By P. H. BOYSON.

HI HENRY'S SHIRT SHOP
252 Pine Avenue
Long Beach, California

Feb. 3, 1928.

Mr. W. P. Graef,
Dist. Mgr., Sou. Calif. Edison Co.,
Long Beach, Calif.
Dear Sir:

Several months ago, Mr. Claude Lindsey, your lighting specialist, convinced me that a change in my window lighting would increase my business and after being thoroughly convinced from his point of argument, I consented to make the change.

Shortly before the holidays last year, the change was made and with only a slight increase in wattage, however, due to the fact that my windows are small, but the readings on my cash register have risen gradually and on making an average of the increase, find that my revenue has increased approximately 30 per cent and while I cannot establish the fact that my better window lighting caused all the increase, I do attribute a goodly portion to it and feel very grateful to your company and Mr. Lindsey for the advice given me in connection therewith, as Mr. Lindsey took exceptional pains to give me a real first class job.

This letter is written with the view that the information contained therein may be of some benefit to some of my fellow merchants.

Yours truly,

HI HENRY'S SHIRT SHOP.
By C. W. HENRY.

Merchandising Bureau Reports

Merchandising*

This year's work of the merchandising bureau was divided into five active committees. The slogan of the merchandising bureau was "load-building." The conclave meetings were given over to the discussion of load-building problems and the specific investigations conducted by various committees were all made in this interest.

Although no special written reports were made for publication, except as referred to under the special committee activities, the following is a brief summary of the work of the five active committees:

* Report of merchandising committee of the merchandising bureau. E. F. Perkins, chairman. F. E. Anderson, H. L. Garbutt, H. C. Goldrick, R. G. Holabird, C. W. Koiner, C. H. Paulin, Frank Talcott, Benjamin Tassie, C. H. Thrane, Frank Weiss, G. S. West, A. I. Whitehead, J. W. Wrenn.

Electric Appliances*

The discussions in this committee's meetings were the promotion of co-operation in appliance sales among all branches of the electrical industry as well as allied merchandisers and improved trade relations.

It is the consensus of opinion that industry's wide campaigns could be better handled if conducted for one month's duration with an intervening month between each special campaign. This recommendation is made due to the time lag which exists in our organizing the merchandising outlets. The general feeling also existed that on such campaigns quality merchandise at list price should be featured to improve the standards of merchandising.

The code of merchandising ethics as adopted by the Commercial Section of the N.E.L.A. received the unqualified approval of the Commercial Section of the P.C.E.A.

The recommendation is made to next year's appliance committee that they formulate plans to be placed in operation which will stimulate the appliance business and result in an improved industry merchandising organization.

* Report of appliance committee of merchandising bureau. A. J. Whitehead, chairman.

Electric Ranges*

The electric range committee for the year 1927-28 undertook three activities, each of which had a definite objective in stimulating load building. There were subcommittees appointed, each of which undertook one of these activities. These committees and their objectives were as follows:

Reports of Subcommittees

1. Subcommittee on Range Sales to Employees. This committee had but one general meeting during the year at which plans for the campaign were outlined but each member kept in touch with the chairman, offering helpful and constructive suggestions.

The matter of increasing employee usage of ranges was taken up with various manufacturers represented locally and special arrangements were made with them, resulting in employees receiving particularly low prices where ranges were purchased for their own use during the period of the campaign.

Letters were then written to the various power company members of the P.C.E.A. with suggestions that employees be urged to install ranges in their homes and take advantage of the special inducements offered by the various manfacturers.

The manufacturers were requested to follow this up with the power companies and later the various power companies were asked for reports.

The total results of the electric range sales to employees were 308 ranges. In the case of one company which had only 11 possible prospects, nine of them were sold, which shows a remarkable record.

This committee recommends that a similar committee be appointed for the coming year as from the response which was received this year and the excellent results shown an effort of this kind is worthy of being continued.

* Report of electric range committee of merchandising bureau. J. S. C. Ross, chairman. F. L. Allen, R. G. Barnett, R. H. Best, H. A. Brody, H. H. Courtright, W. F. Fleming, L. F. Galbraith, C. J. Geisbush, P. S. George, V. W. Hartley, M. S. Hennoch, A. W. Krueger, R. J. Larrabee, D. D. McFarlane, H. J. Moulton, H. T. Simmons, G. C. Tenney, J. W. Wrenn.

2. Subcommittee on Red Seal. The objectives of this committee were to endeavor to further sell the executives and employees of the various power companies to the value of the Red Seal plan as a means of selling electric ranges, and thereby building load.

Activity was conducted in co-operation with the California Electrical Bureau. One committee member was selected to act for each power company in California. A letter was sent to each of the power company committee members stating the objective of the committee's work and outlining a plan of action for carrying out this work. Shortly after this, a standardized talk for Red Seal meetings was sent out to all committee members for their assistance in putting over Red Seal meetings. This talk was prepared by the California Electrical Bureau and covered the following points of the Red Seal plan:

a. What is the Red Seal plan?
b. Why the Red Seal plan?
c. How the plan operates.
d. The value of the plan to the various branches of the industry and its effectiveness in building load for the power company.

This talk was designed to be used with a set of charts which were supplied by the California Electrical Bureau, which showed graphically the points covered.

The results of the committees' activities are tabulated below:

1. Number of meetings of power company managers and employees secured	27
Attendance	932
2. Number of other meetings at which talks on Red Seal were given and which were secured in whole or in part through the efforts of this committee	23
Attendance	10,374

Electric Air Heaters*

This committee has concentrated its efforts on a survey of the commercial heating field, particularly as applied to school heating. A manual is being compiled on this subject which will be printed and ready for distribution at the June convention.

* Report of electric air heating committee of merchandising bureau. O. R. Doerr, chairman. C. E. Allen, H. H. Daley, H. H. Fogwell, A. M. Frost, W. W. Hicks, Arthur Kempston, H. A. Mulvany, J. S. C. Ross, H. E. Sandoval, Adolph Strauch.

Commercial Cooking*

This committee has made a survey of all California installations of commercial cooking equipment and has compiled a manual containing specific information and data relative to California installations which will be published and ready for distribution at the June convention.

The manuals of the commercial cooking and air heating committees are designed to place in the hands of all interested sales parties additional ammunition with which to sell these loads. The manuals will also be of great value to place in the hands of prospects in order to show them what has been accomplished in California.

* Report of commercial cooking committee of merchandising bureau. G. W. Cole, chairman. O. F. Anderson, L. A. Francis, P. P. Pine, H. C. Rice.

Electric Refrigerators*

The activities of the electric refrigeration committee have been retarded due to the lack of interest in this work on the part of electric refrigerator manufacturers and agencies. This committee, however, has a very important message for the industry which will be presented at the June convention.

* Report of electric refrigeration committee of merchandising bureau. H. C. Rice, chairman. Gardner Buss, W. L. Cochrane, Ivan de Jongh, C. E. Hewes, G. J. Ruck, A. L. Spring.

Electric Range Wiring Specifications*

In analyzing the various sales resistances standing in the way of greater development of the electric range market, the electric range committee reached the decision that the high installation cost in houses already wired for lighting service was the greatest obstacle in the way of additional range sales. As a result there was appointed the electric range wiring subcommittee for the purpose of analyzing installation costs in various incorporated cities in California. The subcommittee adopted as its specific objective the drafting of a set of range wiring standards that would permit the installation of an electric range in an old house at an average cost of between $45 and $50.

Past selling experience indicates that there are two fundamental requirements regarding range installation which are generally applicable regardless of the selling agency involved in any range sale. These are: (1) An installation price to the consumer as low as can be consistent with satisfactory operating service and construction permanency. (2) A basis for quoting the "installed price" to the consumer, so that one selling job serves for the whole transaction and minimizes sales resistance otherwise resulting when a range is sold first and the installation job ranging from $50 to $85 has to be sold in addition.

In setting out to draft a new set of range wiring specifications the committee realized that there were certain logical restrictions which must be observed. In the first place the new standards must comply with the requirements of the National Electrical Code. In the second place the standards should be such that at the agreed price of $45 to $50 there would be opportunity for the contractor to make a fair profit. At the same time construction standards would have to be maintained that would assure a high operating efficiency, continuous service and lowest maintenance expense to the customer.

In order to assure success of the committee's efforts it was felt necessary to obtain the co-operation of the Electragists, the Board of Fire Underwriters of the Pacific, and of the California Association of Electrical Inspectors. With this in mind the committee personnel was made up so as to include representatives from each of these organizations.

As an initial undertaking the committee set about to study range wiring standards and costs in a group of representative incorporated cities in California. At the same time data were obtained from various cities in the Pacific Northwest where the greatest strides in electric range selling have been made. The wide variance in electric range installation costs in California cities is shown in Table I.

TABLE I—Range Installation Costs.

	Range Only	Range and Water Heater
Salinas	$52.00	
Stockton	66.75	
San Jose	75.00	
Oakland	69.25	
Sacramento	60.00	
Riverside (knob and tube)	40.00	$50.00
El Centro	45.00	60.00
Fresno	65.00	
Bakersfield	65.00	
San Luis Obispo	50.00	
Merced	55.00	
Seattle, Wash.	40.00	
Portland, Ore. (separate meter)	35.00	
Portland, Ore. (same meter)	45.00	
Tacoma, Wash.	35.00	45.00
Spokane, Wash.	32.50	40.00

It will be observed from Table I that the average installation cost ranges from $40 in the case of Riverside where knob-and-tube wiring is permitted to a maximum of $75 in San Jose. It must be remembered that these are average figures. Isolated instances of costs as high as $105 in Berkeley and $135 in San Francisco were reported to the committee.

In the case of the cities in the Pacific Northwest, the figures given are the costs agreed upon between the central stations and the contractors. The amount quoted in Table I is added to the cost of the electric range and the resulting figure is quoted to the customer as the installed price of the range. Examination of the range wiring standards in the various municipal electrical ordinances in the four northwest cities shows that this low price is not the result of the tremendous development of the range market in those cities but rather the low installation cost has been in no small measure responsible for the thousands of electric ranges that have been sold.

As a result of the various discussions held by the range wiring subcommittee at the Los Angeles and San Francisco conclaves of the Commercial Section there was prepared and submitted at the Fresno conclave the following resolution:

To the California Association of Electrical Inspectors

Mr. H. N. Beecher, President:

As the representatives of the public electrical inspectors are concerned with:

(1) Safety of person and property from electrical accident or fire hazard.

(2) Adequacy of electrical installation which shall provide electrical service to the consumer at a minimum of expense consistent with safety.

The instruments by which electrical inspectors gage the electrical installation for these requirements are the National Electrical Code and the local electrical ordinance.

Public interest in electrical labor-saving and comfort-giving appliances, notably the electric range and water heater, is rapidly increasing. In this public interest the electrical inspector, in common with all other branches of the electrical industry, is involved in that he is asked by the public, which he represents, to secure for it the most economical installation consistent with safety.

Experience shows that some of the requirements for range and water-heater wiring, as set down by the local ordinances and as various interpretations of the National Electrical Code are rendered, are creating installation expense about which the public complains and which results in retarding the furthering of a more general use of these labor-saving appliances.

The Commercial Section of the Pacific Coast Electrical Association, in the interest of making it convenient for the public to make greater use of electric ranges and water heaters, requests the California Association of Electrical Inspectors to urge its members and all electrical inspectors to use their influence toward the establishment of minimum standards of installation for range and water heater wiring.

The Commercial Section of the Pacific Coast Electrical Association further recommends to the California Association of Electrical Inspectors that a committee consisting of three members from their association meet with a like committee from the Pacific Coast Electrical Association to study and formulate minimum requirements for wiring of range and water-heater installations with the purpose in mind that if approved by their association they will be recommended to all municipalities within their jurisdiction for inclusion in their electrical wiring ordinances.

Pacific Coast Electrical Association,
Commercial Section.

Passed at Fresno Conclave, March 21, 1928.

This resolution was passed by the Commercial Section and a special committee composed of W. F. Neiman, Pacific Gas and Electric Company, C. J. Geisbush, California Electragists and H. C. Rice, Southern California Edison Company, was appointed to present the resolution to the inspectors association in convention at Santa Barbara and to meet with a committee of that organization to formulate a set of range wiring standards. At the Santa Barbara convention of electrical inspectors the joint committee representing the power companies, the Electragists and the inspectors themselves, drafted the minimum range wiring requirements shown in Fig. 1. These requirements together with the following set of range wiring specifications to accompany them were passed at the inspectors' convention.

Minimum Requirements For Range Wiring

These requirements apply only to a range installation added to an existing lighting installation in residences.

These requirements apply to cases where the total current demand per wire does not exceed 50 amp. This demand shall be determined on the following basis:

Range circuit.....100 per cent connected load.
Lighting and convenience outlet circuits.....80 per cent connectd load.

The total connected load of the lighting and convenience outlet circuits shall not exceed 3,300 watts.

The requirements for wiring installations prescribed in Articles 1 to 19 inclusive of the "National Electrical Code," 1925 edition, shall be followed, except as otherwise permitted herein. All materials used shall comply with N.E.C. standards.

Service

Service conductors may be three No. 6 wires installed in 1-in. conduit, provided the run has not more than the equivalent of two 90-deg. bends. Service conduit shall terminate in not less than a 60-amp. 250-volt safety-type enclosed switch equipped with 50-amp. fuses

* Report of range wiring subcommittee of the merchandising bureau. G. C. Tenney, chairman. F. L. Allen, O. R. Doerr, W. S. Fleming, C. J. Geisbush, R. J. Larrabee, Claude Mitchell, H. J. Moulton, E. F. Perkins, H. C. Rice, H. E. Sandoval, A. Walthouse.

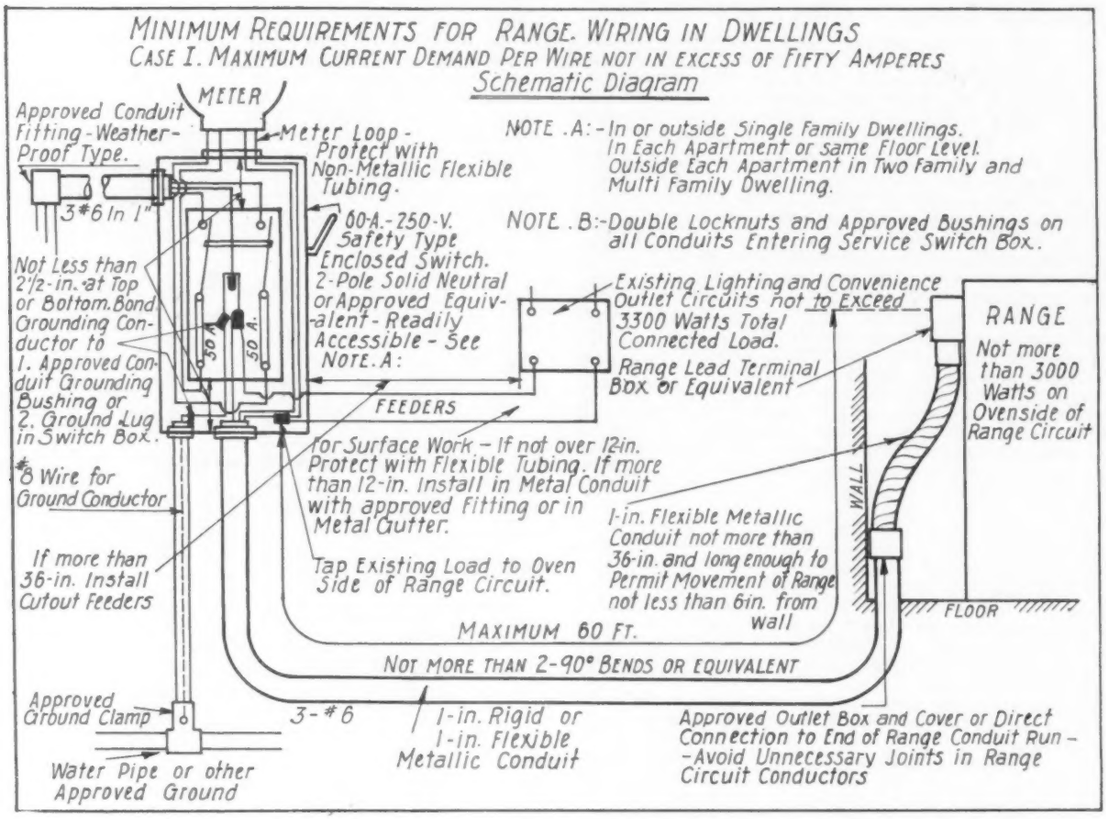
MINIMUM REQUIREMENTS FOR RANGE WIRING IN DWELLINGS
CASE I. MAXIMUM CURRENT DEMAND PER WIRE NOT IN EXCESS OF FIFTY AMPERES
Schematic Diagram
METER
Approved Conduit Fitting - Weather-Proof Type.
Meter Loop - Protect with Non-Metallic Flexible Tubing.
3 #6 In 1"
60-A.-250-V. Safety Type Enclosed Switch. 2-Pole Solid Neutral or Approved Equivalent - Readily Accessible - See NOTE. A:
NOTE .A:- In or outside Single Family Dwellings. In Each Apartment or same Floor Level. Outside Each Apartment in Two family and Multi Family Dwelling.
NOTE .B:- Double Locknuts and Approved Bushings on all Conduits Entering Service Switch Box.
Not Less than 2½-in. at Top or Bottom. Bond Grounding Conductor to 1. Approved Conduit Grounding Bushing or 2. Ground Lug in Switch Box.
50 A.
50 A.
Existing Lighting and Convenience Outlet Circuits not to Exceed 3300 Watts Total Connected Load.
RANGE
Not more than 3000 Watts on Ovenside of Range Circuit
Range Lead Terminal Box or Equivalent
FEEDERS
#8 Wire for Ground Conductor
For Surface Work - If not over 12in. Protect with Flexible Tubing. If more than 12-in. Install in Metal Conduit with approved fitting or in Metal Gutter.
If more than 36-in. Install Cutout Feeders
Tap Existing Load to Oven Side of Range Circuit.
1-in. Flexible Metallic Conduit not more than 36-in. and long enough to Permit Movement of Range not less than 6in. from wall
WALL
FLOOR
MAXIMUM 60 FT.
NOT MORE THAN 2-90° BENDS OR EQUIVALENT
Approved Ground Clamp
3-#6
1-in. Rigid or 1-in. Flexible Metallic Conduit
Approved Outlet Box and Cover or Direct Connection to End of Range Conduit Run - Avoid Unnecessary Joints in Range Circuit Conductors
Water Pipe or other Approved Ground

Fig. 1. Depiction of minimum range wiring requirements worked out by a joint committee representing the power companies, the Electragists and the California Electrical Inspectors.

located where it is readily accessible and within 6 ft. 6 in. of the ground or floor.

Provision for meter shall be made adjacent to service switch.

Range Circuit

The range circuit conductors shall be installed in rigid or flexible conduit or both. At the range end of this conduit run flexible metallic conduit shall be used of sufficient length to permit moving the range not less than 6 in. from the wall.

The range circuit conductors shall not be smaller than three No. 6 which may be installed in 1-in. conduit, provided the circuit run is not over 60 ft. and does not contain the equivalent of more than two 90-deg. bends. If service switch and fuses protect the range circuit conductors, such switch may be used as the disconnecting switch for the range. These switches may be located in or outside of single-family dwellings. In two-family or multi-family dwellings these switches shall be located in each apartment or on the same floor level outside each apartment. This shall not prevent the use of service switches installed on the outside for two-family one-story dwellings.

Existing Lighting and Convenience Outlet Circuits

Where taps of small wire are made to range circuit to supply current to existing cutouts they are not to exceed 3 ft. in length without the protection of a cutout. Where such wires are run as surface work and do not exceed 1 ft. in length they may be protected by non-metallic flexible tubing. Where such wires are run as surface work and exceed 1 ft. in length they shall be installed in approved conduit or metal gutter.

Where taps are made in service switch cabinet a clearance of at least 2½ in. between switch base and cabinet shall be provided on the end where splices are made.

Grounding

Neutral conductor shall be grounded by not less than No. 8 wire run from neutral terminal on line side of service switch to approved clamp on water pipe or other approved ground. This ground wire shall be bonded to an approved conduit grounding bushing or ground lug in service switch box and shall be protected by rigid conduit from service switch box to ground clamp.

The conduit installed for the mechanical protection of this ground wire may serve as the grounding conductor for the service conduit and for the range.

All conduit entering service switch box shall be provided with double locknuts and approved bushings. This construction provides a sufficient grounding bond between the several conduits entering the service switch box.

These requirements are approved by the California Association of Electrical Inspectors for the period of one year beginning March 23, 1928, for the purpose of determining their practicability by field use.

Specifications Approved

These specifications were submitted to the Board of Fire Underwriters of the Pacific for approval. This approval has been received and the inspectors have agreed to give these specifications a trial in California over a period of a year.

The committee feels that this is one of the greatest forward steps taken towards increasing the market for electric ranges in California that has been made in a long period of years. The committee recommends that these specifications be printed and circulated to the entire electrical industry in the state.

Three-Pole Plug and Receptacle

In its study of the range installation problem the committee devoted considerable attention to the question of making the electric range a more portable piece of kitchen furniture. The committee felt that it would be desirable to arrange the range wiring so that it would be possible to transport an electric range from one rented house or apartment to another without the inconvenience of obtaining a contractor to hook up the range.

This problem of easily connecting or disconnecting the range has been solved by the development of a three-pole separable plug and receptacle by both the Arrow Electric Company and the General Electric

Company. By including this receptacle and plug as a part of the range wiring installation the committee feels that the problem of range portability will be solved. This plug will have a rating of 60-amp. at 125-volts, and 40-amp. at 250-volts. It will be placed on the market within a very short time.

In the course of its studies the committee learns that Article 16 of the National Electrical Code was being considerably revised. The proposed revision should be of interest to both central stations and contractor-dealers. The new draft of Article 16 as approved by the N.F.P.A. electrical committee and subject to final approval by the executive committee of the N.F.P.A. and the American Engineering Standards Committee before being included in the code follows:

1601. General.

(a) This article shall be construed to apply only to electrical appliances designed for domestic or general commercial use.

1602. Fixed wiring.

(a) Wiring supplying current to fixed electrical appliances shall comply with Article 5 of this Code except as amended in this article. The insulation on conductors supplying current to appliances shall be as follows:

(1) Type (R) when not exposed to corrosive conditions or temperatures above 120 deg. F. (49 deg. C.)

(2) Type (S. B.) where not exposed to corrosive conditions or dampness, but where temperatures exceed 120 deg. F. (49 deg. C.)

(3) The type of insulation required by Article 5 of this Code, where exposed to corrosive conditions, but not to temperatures above 120 deg. F. (49 deg. C.)

(b) Each electric appliance of more than 20-amp. rating, when used for other than cooking or baking purposes shall be supplied by a separate feeder or circuit, which shall be controlled as required in Section 1603-a.

(d) Demand Factor

The following demand factors may be applied to the computation of feeder wire sizes serving electrically heated cooking and baking appliances of more than 1,650 wats rating:

No. of Electrically Heated Cooking and Baking Appliances of over 1,650 watts rating.	Demand Factors Per cent
1 or 2	100
3	95
5	85
7	75
9	55
11	48
13	44
15	40
17	36
19	36
21	34
23	32
25 and over	30

1602-E Circuit Layout Chart

Each dwelling and apartment shall be provided with the necessary number of circuits of the type or types suitable for the number and character of lights and appliances likely to be used as shown in the above table. Where appliances larger than 6-amp. capacity are likely to be used, as in working spaces, it is recommended that the No. 10 wire appliance circuits given in the table be installed. "Working spaces" include kitchens, dining rooms, laundries and bath rooms.

(a) In computing the floor area the actual area of the "working space" shall be taken first and the difference between that and the maximum, multiplied by four, may be used for the same circuit for "living spaces"; but in no case shall the "living space" maximum allowance be exceeded.

(b) These 20-amp. receptacles shall not be used on both 125 and 250-volt circuits in same occupancy.

(c) It is recommended that each room be provided with at least two outlet receptacles located at different points in order to render unnecessary the use of long extension cords, and the plugging of portables into lamp holders.

1603. Switch Control

(a) Except as in Sec. 1003-g, or as in paragraph (b) of this section, each complete electrical appliance which is required to be supplied by a separate feeder or circuit and each electrically heated cooking or baking appliance of more than **1650** watts, shall be controlled by a separate indicating switch or an approved attachment plug and receptacle, either of which shall at one operation disconnect all ungrounded conductors of the feeder or circuit by which the appliance is supplied. This switch shall not be on the appliance.

(b) The separate indicating switch required in paragraph (a) of this section shall be located so as to be invariably accessible to the operator of the appliance.

In single family dwellings the switch required in paragraph (a) of this section may be the service switch. (See Art. 4 of this Code.)

In two-family dwellings the switch may be outside of the apartment in which the appliance is installed but must be accessible. This will permit the service switch for the building to be used provided it is accessible to the user of the appliance.

In multi-family dwellings (more than two) the switch required in paragraph (a) of this section shall be within the apartment or on the same floor as the apartment in which the appliance is installed and it may control lights and other appliances.

In other than dwelling occupancies the switch required in paragraph (a) of this section shall control nothing but the appliance.

Where the separate indicating switch is required under paragraph (a) of this section for a motor appliance, it shall be invariably within sight of the appliance.

(c) Except under conditions set forth in Sec. 1003-g, switches controlling the individual units of electrical appliances shall not be considered as taking the place of the separate indicating switch required in paragraph (a) of this section.

1604. Cords and Plugs

(a) Each portable electrical appliance shall be equipped or provided with a single cord and plug connector approved for use therewith so designed that the plug may be pulled out to open the circuit without leaving any live parts so exposed as to render likely accidental contact therewith. The connector may be located at either end of the flexible cord, or it may be inserted in the cord itself.

(b) Stationary electrical appliances may also be connected with the circuit supplying them with current by means of a single cord and attachment plug approved for use therewith.

1605. Grounding

(a) Electrical appliances shall be grounded where and as required by Art. 9 according to location and occupancy concerned and with the exemptions provided for in Art. 9.

For purposes of this section "fixed appliances" shall be considered as those exceeding a rating of 20-amp. (See circuit layout in Paragraph 1602.-E.)

1606. Name Plate

Each electrical appliance shall be provided with a name plate, giving the maker's name and the normal rating in volts and amperes, or in volts and watts.

1607. Exposure to Combustible Material

(a) Each smoothing iron and other portable electrically heated appliance, which is intended to be applied to combustible material, shall be equipped and used with an approved stand, which may be a separate device or may be a part of the appliance.

(b) In other than residence occupancies each such electrically heated appliance or group of such electrically heated appliances shall be used with an approved signal, unless the appliances are provided with approved temperature limiting device built into the structure.

(c) Flexible wires supplying portable electrically heated appliances rated at more than 50 watts and which produce temperatures in excess of 250 deg. F. (121 deg. C.) on surfaces with which the flexible wires are liable to come in contact shall comply with section 603-d-11 (1925 Code Type H. Cord). For other portable electrical appliances which do not produce exposed surface temperatures above 250 deg. F. (121 deg. C.) approved cord (Type C), or other cord specially approved for the purpose shall be used (See Sec. 603-c).

(d) Each electrically heated appliance which is obviously intended by size, weight and service to be secured in a fixed position shall be so installed as to furnish ample protection between the appliance and adjacent combustible material.

TABLE II—Circuit Layout Chart.

Wire Ga.	Wire Amp.	Fuse Base Amp.	Use	Outlets	Allowable Areas Per Circuit: Working Spaces Max. Per Cir.	Allowable Areas Per Circuit: Living Spaces Max. Per Cir.
No. 14	15	15	Lights Only—No Appliance cir. in same rooms	660 watt Sockets only	150 sq. ft.	600 sq. ft.
			Lights Only—With Appliance cir. in same rooms	660 watt Sockets only	1,200 sq. ft.	1,200 sq. ft.
			Lights and Appliance	660 watt Sockets and Lamp Receptacles	150 sq. ft.	600 sq. ft.
			Appliances and Portables	15-amp. Receptacles only	300 sq. ft.	1,200 sq. ft.
No. 10	25	30	125-volt Appliances and Portables only	15-amp. Receptacles	600 sq. ft.	1,200 sq. ft.
No. 10	25	30	125-volt or 250-volt Appliances	20-amp., 250-volt receptacles (See Note B)	Limited to 125-250-volt Grounded Neutral Circuit. No Area Limitation.	

Recommendations

This committee recommends that the subject of range wiring standards and installation costs be followed closely during the next administration year. It recommends that a report be prepared on the operation of the new range wiring standards as adopted and also on the resulting installation cost in various California cities.

Power and Heating Bureau Reports[2]

Competitive Power—A Study of a Municipal Power Plant

By A. W. Chawner*

The competitive power committee has given attention to the study of steam and Diesel-driven isolated plants for operation of hotels, hospitals and municipal uses. Many committee meetings have been held, resulting in discussion of great value to committee members.

The following study of operation of a municipal power plant for pumping water and generating electricity, submitted by W. R. Chawner, of the Southern Sierras Power Company, is a typical example of committee work undertaken.

An American Society of Mechanical Engineers test was conducted on a municipal Diesel plant and the following figures obtained. The allocation of wage cost is considered on the low side, but the actual figures for repairs, maintenance and depreciation over a period of seven years were obtained from the city treasurer's vouchers as regards the two 120-hp. engines.

Original cost of these two engines was shown as $22,060; 6¼ per cent maintenance and 7 per cent depreciation for seven years, $20,461.

Cost Per Kw.-hr. Generated

	Cents
Fuel	0.581
Lubricating oil	0.053
Cooling water	0.051
Stores	
Wages	1.53
Repairs and maintenance	0.594
Operating total	2.809
Interest	0.870
Depreciation	0.871
Insurance	0.136
Total cost	4.686 per kw.-hr.

Summary of Analysis of Annual Costs at Main Meters of Power for Pumping Water and Generating Electricity for Light and Power

Installation—3 Diesel engines totaling 405 hp.

Capital	$62,638
Fixed charge	8,192
Maintenance	2,797
Labor	7,200
Fuel oil	2,732
Lubricating oil	250
Compensation insurance	640
Cooling water	241
Total	$22,052

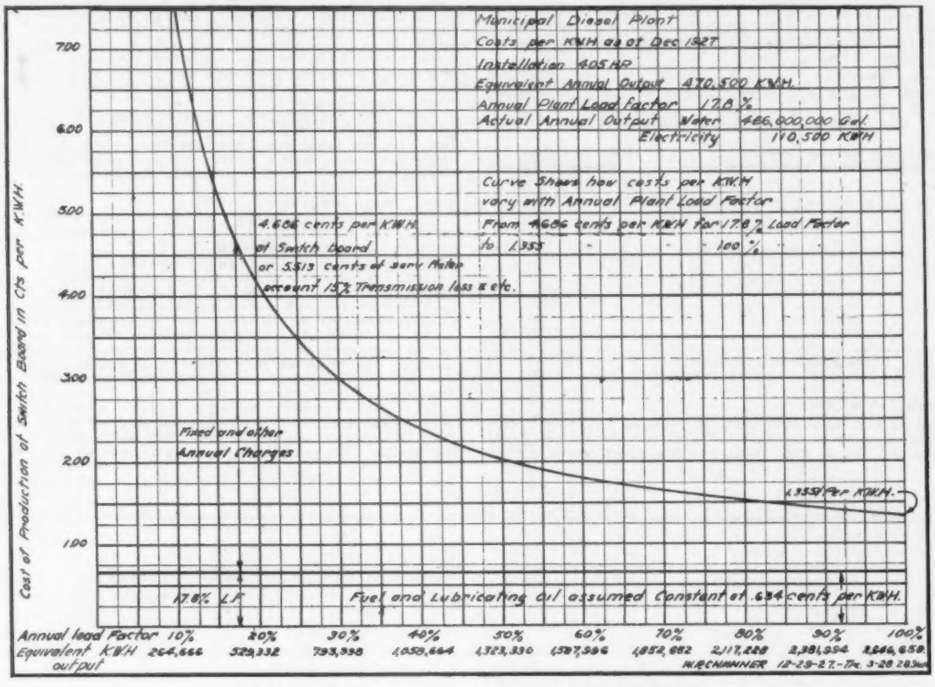
Municipal Diesel Plant
Costs per KWH as of Dec 1927
Installation 405 HP
Equivalent Annual Output 470,500 KWH
Annual Plant Load Factor 17.8 %
Actual Annual Output Water 466,000,000 Gal
Electricity 110,500 KWH
Curve Shows how costs per KWH vary with Annual Plant Load Factor
From 4.68c cents per KWH for 17.8 % Load Factor
to 1.35 " " 100 % "
4.68c cents per KWH at Switch Board or 5.513 cents at any Meter account 15% Transmission loss & etc.
Fixed and other Annual Charges
1.35¢ per KWH.
17.8% L.F.
Fuel and Lubricating oil assumed Constant at .634 cents per KWH.
Cost of Production at Switch Board in Cts per KWH.
700
600
500
400
300
200
100
Annual load Factor 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Equivalent KWH output 264,666 529,332 793,998 1,058,664 1,323,330 1,587,996 1,852,662 2,117,328 2,381,994 2,646,659
W.R.CHAWNER 12-29-27-Th. 3-29-28-Th.

Fig. 1. A study of output costs of a Diesel-electric plant.

Actually these engines were rebuilt by the manufacturers and recommissioned. The total cost for repairs and rebuilding over the seven years amounted to $21,032.

In the case under review repairs, maintenance and depreciation cost 1.465c per kw.-hr.

Municipal Diesel Plant Annual Costs

Kw.-hr. generated	470,500
Number of engines	3
Maximum load	135 kw.
Total installed	405 kw.
Annual load factor	17.8%
Cost of fuel oil per lb.	0.686c
Cost of lubricating oil per gal.	38c
Fuel used per kw.-hr. generated	0.846 lb.
Lubricating oil used per kw.-hr. generated	0.001396 gal.

[2] A. M. Frost, San Joaquin Light & Power Corporation, chairman.

* Report of the competitive power committee of the power and heating bureau. W. P. Bear, chairman. W. L. Boxall, C. H. Coulter, J. H. Cunningham, G. A. Frazier, Charles Grunsky, T. C. Johnson, W. G. Lane, M. P. Lohse, P. P. Pine, Maurice Rhine, W. J. Walsh.

Annual plant load factor, 17.8 per cent.
Total output equivalent, 470,500 kw.-hr.
Average cost per kw.-hr., 4.7 per cent.

	Total Cost
Electrical output, 110,500 kw-hr.	$ 5,200
Pumping water, 466,000,000 gal.	16,852
Total	$22,052

Pumping water cost 3.61 cents per 1,000 gal.
Electrical cost 4.7 cents per kw-hr. at switchboard or with transmission loss of 15 per cent:
Electrical cost, 5.5 cents per kw.-hr. at submeters.

Municipal Plant Analysis of Annual Costs Water, Light and Power

The following figures are arrived at from a perusal of the city demands on the municipal treasury.

Capital Cost:

Two 120-hp. enginers	$22,060
One 165-hp. engine	15,357
Electrical equipment	11,598
Building	10,000
Compressors, fuel tanks, etc.	3,623
	$62,638

Basis of Annual Fixed Charges:

	Per Cent
Interest on capital investment	7.00
Depreciation on engines	7.01
Depreciation on electrical equipment	5.00
Depreciation on building	1.50
Maintenance on engines	6.25
Maintenance on electrical equipment	2.00
Maintenance on building	1.00
Taxes exempt	

Insurance carried only on building, $100 a year.
Compensation insurance $7.62 per $100 wages.

In the following we exclude maintenance on engines and electrical equipment and compensation insurance from the fixed charges and set these up as is more proper in the production cost.

Annual Fixed Charges:

Engines, 14.01 per cent on	$41,040 =	$5,750
Building, 9½ per cent on	10,000 =	950
Electrical equipment 12 per cent on	11,598 =	1,392
	$62,638	$8,092
Insurance on building		100
Taxes		.....
Total annual fixed charges excluding maintenance and compensation insurance		$8,192

Maintenance:

Maintenance 6¼ per cent on engines	$41,040 =	$2,565
Two per cent on electrical equipment	11,598 =	232
	$52,638	$2,797

This figure of 6¼ per cent checks closely with the actual repair bills paid on the two smaller engines which together with the cost of rebuilding these two engines amounts to $21,032 for maintenance and depreciation for 7 years.

Original Cost $22,060:

Six one-quarter per cent maintenance and 7 per cent depreciation on $22,060 for 7 years = $20,461.

Labor—Attendance and Maintenance and Automobile Repair Shop:

The monthly wage bill at the water plant would appear to be, excluding executive salary:

One chief engineer	$225
One mechanic	200
One shift operator	150
One shift operator	135
One shift operator	135
	$845

And in addition one mechanic at $175, employed as required exclusively on automobile repairs.
A fair allocation of this monthly wage bill would seem to be:
Three engines, $600. Water department, $100. Auto repairs, $145 per month.
This would give an annual attendance charge of $7,200.

Agricultural Power*

The agricultural power committee also has conducted some studies and made some experiments in soil heating for expediting plant growth. Results, so far, indicate possible success, particularly with asparagus.

The results of the test indicate that with the application of from five to eight watts per row-ft. between the periods of Jan. 15 to March 1, the producing season of asparagus could be advanced approximately three weeks, the grower receiving the benefit of greatly increased price for his product when produced out of season.

The heating of asparagus beds would require the installation of approximately 40 kw. per acre, but it is believed that by taking advantage of sunlight, desired results could be secured with the consumption of 15,000 kw.-hr. per acre per season.

Additional facts will be determined from experiments which are to be conducted in the future.

Hand-Book to be Published

The agricultural power committee has devoted its work during the past year almost exclusively to the gathering and assembling of data on various applications of electric power service to agriculture, for the purpose of compiling a hand-book for the use of power salesmen in their work with agricultural consumers.

Much valuable data have been collected during the past year which will be carefully edited and prepared for publication during the administrative year 1928-1929.

In order that the information so far accumulated may be available for use by interested parties prior to the publication of the hand-book, the following resume of subjects covered is given.

If further detail on specific application is desired, it may be secured by communicating with E. G. Stahl, San Joaquin Light & Power Corporation, Fresno, chairman of the committee.

Agricultural Pumping

By F. E. Anderson

Data have been gathered on the following subjects:

Cost of drilling wells.
Data on well casing.
Cost of well casing.
Developing of wells.
Prices and operating data on turbine and centrifugal pumps.
Approximate prices on electric motors.
Cost of installing deep weel turbines.
Wiring costs and switchboard requirements.
Data on pump house and derrick installations.
Water duty.
Sizes of plants for various acreages under varying head conditions.
Pump efficiencies.
Hydraulic and electric formulas.
Weir tables.
Data on overhead irrigation systems.
Other data of a general nature, designed to qualify for power company salesmen.

Domestic Pumps

By F. E. Anderson

Data have been collected on various types of domestic electric water pumps, dealing both with gravity and air pressure tank systems, giving capacities, horsepower and approximate prices.

Data also are available on quantity of water required for farmhouse use, and for use of domestic animals.

Applications of Electric Service to the Dairy Industry

By A. W. Frost

Data are available on the economic advantages to be derived from use of electrically operated milking machines, dealing with various types of milking machines manufactured, their operating cost and labor saved.

Electric Dairy Sterilizers

By A. W. Frost

Data have been gathered on state law requirements for sterilization, types, capacities and operating costs of electric sterilizers now being merchandised, showing distinct advantages of the application of electricity to this service.

Separators

By A. W. Frost

Available data have been assembled from manufacturers and other sources on the economic value of this type of equipment to users.

Milk Cooling

By A. W. Frost

Where an abundant supply of cold water, 50 deg. F. or below, is available, milk is frequently cooled and sometimes stored by the use of water only. As a rule the water is pumped from a shallow well, through the milk cooler by a ¼-hp. motor. The maximum energy consumption during July and August is 10 kw.-hr. per month, and the minimum during February was found to be 4 kw.-hr., making the average for the year 7-8 kw.-hr., or 2.6 kw.-hr. per 100 quarts per day.

A range of from 2.5 to 3.5 kw.-hr. per month for each herd of 10 cows should be sufficient for cooling where water is pumped from a shallow well. When water is used for storage, the average consumption is increased 50 to 100 per cent.

Milk Cooled by Refrigeration

All large dairies cool their milk by refrigeration where the milk is to be distributed to local consumers. Different types of refrigerators are used; also large ammonia plants are used. This type of cooling is most advantageous as it provides storage space and a large amount of ice which can be used around the dairy and also for packing purposes while en route to the consumer.

* Report of agricultural power committee of the power and heating bureau. E. G. Stahl, chairman. F. L. Allen, F. E. Anderson, F. D. Beardsley, H. E. Brillhart, L. J. Brundige, A. W. Frost, P. S. George, B. D. Moses, R. C. McFadden, L. J. Nevraumont, D. B. Wheelock, C. T. Yates.

Milk is brought from the milking barns and poured into the strainer tank, and from there it trickles over the outside of the cooled aerating coils and then into the trough at the bottom of the coils and into the cans, and is then placed in the cooler or refrigerating compartment until time of delivery. The cold storage is usually kept just above freezing.

In some installations the milk, after flowing over the aerating coils being cooled to 40 deg. F., is piped to a tank that is connected to a bottling machine and then placed in cold storage, ready for delivery. As a rule retailers use this method, while the first method is used by wholesalers.

The aerating coils are tinned copper tubing and usually divided into two sections so that the upper section is cooled by circulating water through it and this gives the warm milk its initial cooling at much less cost than by doing it with brine, all of which has to be cooled by the refrigerating machine. The lower section is always cooled to a much lower temperature than possible with water, by circulating brine through it. When the milk has passed over the brine cooled tubes, its temperature, as it leaves the collecting trough at the bottom of the aerator, is usually about 40 deg. F.

If water is not available for cooling the upper section of the aerator, of course brine may be used, but the cost for electric current will be more. Dairymen usually depend on water circulating flow by means of pressure from an elevated tank, or an automatic pressure pump, electrically driven, where city water is not available.

The circulation of the brine is by means of a centrifugal pump, in most cases driven by a small direct-connected electric motor, so that it can be operated independently of the refrigeration machine, rather than belted to the flywheel of the compressor.

Operation of Arden Dairy in Southern California—The Arden Dairy of El Monte, Calif., is one of the largest dairies in the state and handles pasteurized milk only. The following is the method of procedure:

The milk is brought from the milking barns to the milk house and poured into a strainer tank, from which it is run through a filter, and from there through pipes to two 500-gal. double-wall cooling tanks. These tanks are cooled by a constant spray of brine on the inner walls from perforated brine pipes run between the inner and outer walls of the cooling tank. The brine is circulated by an electric pump. The milk in the cooling tanks is continually mixed in order to obtain a perfectly unform grade of milk by large paddles driven by an electric motor through a reducing gear at a very low speed. The milk is cooled to 40 deg. F. in this cooler and then flows through pipes directly to the bottling works, which is operated by an electric motor. After the milk is bottled, it is placed in three large refrigerators kept for that purpose, the temperature of which is 33 deg. F.

The Arden Dairy makes all its own ice, the output being 1,200 lb. per day in the winter months and 2,400 lb. in the summer months. This is used on the delivery wagons for packing the bottled milk, and in this way it reaches the consumer in a first-class condition. The Arden Dairy furnishes certified milk only, and is a model dairy in every sense of the word.

The following is a statement of cost of operation of cooler and storage from six different dairies. The dairies are all small with the exception of No. 6, which is the Arden Dairy.

TABLE I.

Dairy electric refrigeration and milk-cooling data	Dairy No. 1	Dairy No. 2	Dairy No. 3	Dairy No. 4	Dairy No. 5	Dairy No. 6
Total connected load—horsepower	8	3	5	1¾	1½	100
Refrigeration load—hp. (Compressor	3	1½	3	1½	1	20
(Brine pump	½	¼	½	¼	¼	3
Kind or make of refrigeration plant	Ammonia plant	Ammonia plant	Ammonia plant	Sulphur dioxide	Methol chloride	Ammonia plant
Size of refrigerated milk storage vaults (Approx.) in ft	10x3x6	6x8x6	10x7x7	None	6x8x6	18x22x12 and 6x10x8
Ice making capacity installed in addition to refrigeration—same machine handles both	None	None	None	None	120 lb	4,000 lb.
No. of cows	80	50	75	90	30	570
Gallons of milk per day	300	170	280	320	100	1,710
Average kw.-hr. per month used on refrigeration plant	Est. 1,200	Est. 490	Est. 800	458	287	Est. 7,500
Average monthly bill chargeable to refrigeration plant	Est. $23.40	Est. $11.03	Est. $17.44	$9.34	$7.84	Est. $127.50
Average cost per kw.-hr. for current used	1.95 Cents	2.25 Cents	2.18 Cents	2.039 Cents	2.73 Cents	1.7 Cents
Average cost per gallon of milk cooled or cooled and stored	2.6 Mills	2.16 Mills	2.07 Mills	0.97 Mill	2.61 Mills	2.48 Mills

Utility Motors

By F. E. Anderson

Costs of portable units, single-phase and multi-phase, 3-hp. to 7½-hp., showing motor required and kw.-hr. consumption for hay hoists, corn shredders, ensilage cutters, and feed grinders have been gathered; also farm applications for the operation of forges, lathes and tool sharpeners.

Data gathered also carry cuts of electrically operated equipment.

Hay Balers

By D. B. Wheelock

Data were gathered on the actual operation of electric hay balers in the Imperial Valley, dealing with motor requirements and giving as cost of operation from ½ to 1 kw.-hr. per ton of hay baled.

Operating hay hoists with electric motor is also dealt with under this subject.

Stationary Spray Plants

By F. D. Beardsley

This report includes description of a piping layout in an orchard, the pumping station and storage tanks required, economic advantages, method and cost of operation.

Dehydration

By R. C. McFadden

Information has been collected dealing with actual performance of electrically heated and motor operated walnut dehydrators in southern California. An analysis of the data show, among other advantages, those of reduced fire hazard, exact temperature control, uniformity of weight, and ability to operate this class of equipment irrespective of climatic conditions.

Electrical dehydration results in a much shorter harvesting period, which makes it possible to put the walnut crop on the market at a more desirable season.

Electricity in the Poultry Industry

By L. J. Brundige

Subjects covered include:

Electric incubation.
Electric brooding.
Lights for winter egg production.
Use of violet light.
Candling eggs for fertility in market.
Cleaning stains from eggs.
Sealing or processing eggs for storage.
Grinding and mixing mash.
Chopping fodder.
Pumping and heating of water.
Ventilation.

Operating characteristics of equipment available, with current consumption and cost of operation for various applications are obtainable.

Yard Lighting

By R. C. McFadden

This report deals with general lighting and local lighting, showing wiring diagrams, and giving recommendations for selection of equipment, as well as convenience and economic advantages.

Pest Control

By R. C. McFadden

The use of light as a means of killing flying insects which either in themselves or through the eggs which they lay are injurious and destructive to growing crops has been very successfully demonstrated in different parts of the United States.

In most instances the methods used are similar in that a brilliant source of light is provided in the field and directly under this light source is placed a pan or vessel containing water and kerosene. The insects being attracted to the light eventually fall into the oil and water and are drowned.

The installations on which data have been obtained vary in character from the distribution of four 100-watt lamps per acre equally placed, to a concentrated light source of 3,000 watts in the center of a 60-acre field. In the latter case this plan was adopted after considerable experimentation. It was found that a very much greater quantity of insects could be killed with the highly concentrated light source. Using this system, four to five gallons of millers and other insects were caught nightly for about four nights, after which the nightly catch diminished.

The crops protected in this way were corn, lima beans and tomatoes. According to the rancher, "the use of light for killing flying pests not only does away with the necessity for the use of spraying and poisons, but is much less trouble and very inexpensive. I would not think of raising sweet corn or tomatoes for the market without the use of light. If lights are put out early enough, there need be no sweet corn on the market with worms in the ears."

In order to obtain the best results, light should be used from dusk to daylight all during that period when the growing crop is subject to damage from insects; this, of course, will vary with the particular crop. Experiments in tomato growing have shown a reduction of from 30 per cent to 50 per cent in infestation to virtually zero per cent when light was used.

Watts per acre for pest control, from data available, vary from 50 to 400, which, for an average of ten hours burning, will give a kw.-hr. consumption varying from ½ to 4 kw.-hr. per acre per night.

Another interesting application of light for pest control has been successfully used for the eradication of gnats. This installation consists of a 200-watt lamp mounted under a circular reflector. This was placed about 8 in. from a cylinder 10 in. in diameter and 12 in. deep, at the bottom of which there was suspended an ordinary exhaust fan and around the base was fastened a bag. The gnats being attracted to the light would be sucked down through the cylinder into the bag by the action of the fan. Traps of this character caught about 10 lb. of gnats per night and it was estimated that each pound contained at least 1,000,000 gnats.

The use of light as a pest control has been taken up for study by the California Committee on the Relation of Electricity to Agriculture.

Industrial Heating*

This report of the industrial heating committee for 1927-28 is in the nature of a progress report covering the three major assignments taken up and now under study by the committee.

The industrial heating handbook was started in loose-leaf from three years ago, and has been added to each year. This book is designed for the use of power salesmen and industrial heating specialists. It contains photographs and operating data of typical installations, with emphasis on Western applications. During the present year additional photographs have been secured, and recent N.E.L.A. bulletins of industrial heating application have been distributed so they may be incorporated in the handbook. From the reports received this handbook has proved to be of great value, and the committee recommends that it be kept up to date by the industrial heating committee each year. The subcommittee in charge of this activity was headed by E. J. Cipperly and C. R. Owens.

Another important assignment was a survey of existing heating installations in the territory covered by this association. This work is only partially completed and it is suggested that it be continued and completed by next year's committee.

From the partial returns received, it appears that there are at present more than 50,000 kw. of industrial heating equipment now connected in California using 70,000,000 kw.-hr. annually.

The third major assignment was a study and survey of new fields for industrial heating applications. This work, under the supervision of H. H. Fogwell and E. J. Cipperly is well under way, but is not completed at the time this report is written. It should be carried as an activity next year.

In general, it has been the aim of the committee to supplement the excellent work being done by the industrial heating committee of the Commercial National Section by making available appropriate Western data, rather than to duplicate the studies which are being made by the national committee.

* Report of the industrial heating committee of the power and heating bureau. J. L. Farley, chairman. W. L. Boxall, L. J. Brundige, E. J. Cipperly, H. H. Fogwell, Lloyd Henley, E. V. Kane, J. M. Lee, C. R. Owens, P. P. Pine, R. B. Plass, E. F. Sixtus, C. R. Sullivan, Jack Wells, E. A. Wilcox, L. C. Williams.

Engineering Section[1]

Accident Prevention Committee Reports[2]

Education of a Line Foreman in Accident Prevention Methods

By J. R. Rowe*

Looking at accident prevention from the angle of safety education, our focus is first drawn to the foreman as the most important link in our chain of education of men and the best disciple a safety engineer can have in the field to help his program.

This is particularly true with public utilities, and probably no other branch of industry is so dependent upon foremen, gang foremen especially, to maintain safety conditions and uphold and enforce safety rules and practices.

The line crews with a foreman in sole charge seldom see or know any other official in the organization or have cantact with any central point from which safety propaganda may be disseminated. A new man entering the gang knows nothing more of a company's policies or wishes than those he receives from his foreman.

To have a good, open-minded, progressive and alert

[1] **C. F. Gilcrest,** San Joaquin Light & Power Corporation, chairman. **N. B. Hinson,** Southern California Edison Company, vice-chairman. **The California Oregon Power Company:** P. O. Crawford. **Coast Counties Gas & Electric Company:** W. R. Van Bokkelen. **Coast Valleys Gas & Electric Company:** T. W. Snell. **General Electric Company:** A. G. Jones. **Los Angeles Gas and Electric Corporation:** J. G. Rollow. **Ontario Power Company:** A. J. Hall. **Pacific Gas and Electric Company:** L. J. Corbett, R. R. Cowles, F. R. George, H. A. Laidlaw, C. E. Young. **San Diego Consolidated Gas and Electric Corporation.** C. W. Wiggins. **San Joaquin Light & Power Corporation:** E. J. Crawford. **Southern California Edison Company:** J. M. Gaylord, Harold Michener. **The Southern Sierras Power Company:** M. S. Slaughter. **Westinghouse Electric & Manufacturing Company:** R. A. Hopkins.

* Report presented to accident prevention committee.

[2] **W. E. Row,** Southern California Edison Company, chairman. **F. S. Thomas,** Coast Counties Gas & Electric Company, vice-chairman. **The California Oregon Power Company:** S. M. Bullis. **Central Arizona Power Company:** R. T. Richards. **Los Angeles Bureau of Power and Light:** W. L. Smith. **Los Angeles Gas and Electric Corporation:** J. R. Rowe. **San Diego Consolidated Gas & Electric Company:** W. E. Richmond. **San Joaquin Light & Power Corporation:** J. M. Buswell. **Southern California Edison Company:** D. G. Macey. **The Southern Sierras Power Company:** M. S. Slaughter. **Westinghouse Electric & Manufacturing Company:** P. B. Garrett.

foreman in charge of those crews is to have a safe and efficient crew as soon as safety education is started. Too often, however, a line foreman was only a good lineman advanced because of long years of service and sometimes because of injuries incapacitating him from active work, and he is therefore not alert and progressive. These men usually give little thought to safety other than that forced upon them and they even resent an organized attempt at education of their men in safe thinking and working. It is even found that these foremen will be very hostile. to the new man who is practicing safety and brings some new and safer methods of work to a crew.

This type of foreman, while presenting a more difficult problem, must be carried along with the others and educated into safety before any thought can be entertained of safety education for his men.

I believe the first attempt to be made with all of them is to sell the safety idea to them and make each foreman realize the importance of his position in a safety program; that without his support and cooperation, there can be no real safety program among his crew. This can usually be accomplished rather easily by starting with personal letters of information and appeal, articles from magazines and posters, talks before group meetings, and individual talks to each man right out on the job.

This usually creates the desire to learn and this desire can be helped by showing the men records of what has been done in other crews or companies when safety work was made a part of the regular work.

Then follows an incentive to learn and accomplish something and this can probably best be done by issuing every month to each foreman a complete report of all accidents to men in other crews and departments. These reports should be comparative and have each foreman listed according to percentage of his accident experience for that month. Besides a chart of the foremen's standing, there should be a report of each accident giving the name of the man, his foreman's name, and details about the accident and subsequent injury. These reports create and maintain a competitive spirit among foremen that will make them wish to be always at the top and try pretty hard to stay there. The details of the accident will also serve as information for a foreman in attempting to prevent a smiliar accident in his own crew. These monthly reports should be supplemented with quarterly, semiyearly, and yearly reports of the foreman's standing for those periods.

Other ways of stimulating the incentive to learn and maintain good records is to offer bonuses, prizes, merits, trophies, etc. These, however, are regulated by company policy and local conditions.

After a foreman is educated to a point where he wants education, then it is comparatively easy. In fact, he usually demands knowledge and instruction along all lines of safety. It has been found in the experiences of this company that starting with a course of first-aid instruction proved very beneficial as a kindergarten of safety instruction. This course, consisting of five consecutive days of two hours each day, allowed ample time to bring in short safety talks and discussions in addition to the regular prescribed first- aid work. This initial course should be followed in a few weeks by a "safety school" consisting of about six meetings extending over a period of six weeks, or one each week. At these meetings, outside speakers should be brought in for the main lecture, and then should follow a discussion of accidents and an open forum regarding the safety methods and ideas of each man. The intent of such meetings, of course, is to keep each foreman thinking, talking, and exchanging ideas for safety of work and men.

Such courses as these may subsequently be held every few months and especially reviews in first aid should be held regularly every three or four months.

The intervals between these courses should be filled with an endless stream of publicity, consisting of reports, records and letters addressed to the foremen in which current accidents and near accidents are reported and explained, new safety kinks or ideas broadcast from other foremen, etc.

A regular monthly meeting of foremen should be kept up the year round as discussion of current accidents and other matters of vital interest will always fill these meetings.

Education of men in first aid should follow soon after the formen's courses and the men's interest in the monthly comparative records should be solicited; but the foremen should have reviews and new courses often enough to keep them always ahead of the men under them. If a foreman finds he is taught no more than the men under him his interest will lag.

Disciplinary Measures in Accident Prevention Work

By W. L. Smith*

Lewis A. DeBlois has written in his book, "Industrial Safety Organization," the following statement: "In a field of endeavor as new as accident prevention little dependence can be placed on the control of the individual through his acceptance of what is deemed common practice, for no real body of common practice has yet been established, and for the present we must rely almost entirely upon control by rule, supervision and direct instruction."

Safety rules, therefore, are of real importance in the administration of discipline in accident prevention and any company or organization making such rules should give careful consideration to their preparation. On the other hand, as Mr. De Blois has stated, "because so sacred a possession as human life is involved, their observance must be insisted upon, for without reasonable enforcement they are not only useless but weaken all other efforts to maintain safety. To the new man, always unfamiliar with his surroundings and unacquainted with the hazards of his new occupation, rules are meaningless and unimpressive until he realizes that they will be enforced."

Safety rules, to bring about the desired result in the conduct of employees, must have clearness and purpose and their usefulness and practicability must be without question, they should not be circumscribed by arbitrary requirements, as their real purpose primarily is for the instruction of the employee and only secondarily as a basis for discipline.

It might be stated here that a book of safety rules which the employee can carry home for study or keep in his pocket for reference, and which contains a segregation of rules pertaining exclusively to safety in his particular department, represents the best recognized practice.

The enforcement of safety rules must be rigid, impartial but not harsh; judgment should not be hasty, action being delayed until all the facts are produced. Neither the length of service, the value nor the position of the offender should be permitted to interfere with decisive action taken for the good of the service; the factors of service, value and position should be given consideration in determining the nature of the penalty but should not affect the question of enforcement itself. To do so otherwise will weaken the entire safety effort.

The penalties for infraction of rules should be selected in advance, although to avoid possible embarrassment in difficult cases it may be inadvisable to make them public. While theoretically the penalty for infraction of a given rule should always be the same, such is not practical and each case must be judged on its own merits. There are a great many things that must be taken into consideration such as the nature of the infraction, the circumstances leading up to it, the intelligence of the man and his understanding of the rule, his age, experience, value and position.

Two things are paramount in discipline: the effect on the man himself, the effect on the body of employees and the company's safety movement. If the infliction of the penalty will make the plant safer for all, it should be inflicted; if only the man himself is affected and it will make him a safer man, it ought to be inflicted. If it is felt the penalty has the opposite of the desired effect, the question of discipline should not be dropped but some other form of penalty should be considered. If a man is injured as a result of breaking a rule, the question of penalty should not be dismissed on the assumtion that he has suffered enough and learned his lesson. Surely a follow-up investigation of the man's attitude toward the broken rule should be made. If he is a repeat and cannot be corrected, it is better that he be transferred to other employment or dismissed as soon as possible for he constitutes a hazard to other employees. On the other hand, if he has been treated fairly and is in the right attitude of mind and

* Report presented to accident prevention committee.

susceptible to safety teaching, there is a fine opportunity of making him a safety man.

The following measures are suggestions and may be used as a guide in the administration of discipline: first, where no accident results from violation of rule, the first offense should be disciplined by a warning; second, in the second offense a lay-off from to three to seven days; a third offense usually warrants a dismissal from service. As an alternative to the above penalties sometimes a temporary demotion to a less important or desirable job at a lower rate of pay is effective as a corrective measure in discipline. A decrease in the rate of pay for the same work or job will almost always cause an unfavorable reaction. Suspension as a penalty is usually less effective as a disciplinary measure, as it is apt to increase the hardship on the employee's dependents, thus engendering resentment.

It seems desirable that a reprimand should never be given publicly or even before a committee, as ridicule is not only feared but it is apt to awaken resentment in the employee.

To break up a wholesale disregard for a general safety rule it may be necessary to dismiss the most prominent individual who fails in his duty of seeing that it is enforced as, for example, the dismissal of a foreman for his failure to enforce the rule of wearing goggles, rubber gloves, etc., or he may be given the alternative of preparing and presenting a paper or address an the subject of this particular feature of safety before the employees.

If panalties are applied for their moral effect on the general body of employees it seems obvious that publicity should be given to what has been done. If this is neglected the result may be a distorted version of the truth being broadcast, and the opposite effect of the one desired may be obtained. Where a penalty more severe than a reprimand is applied, a brief description of the circumstances, reference to the broken rule and statement of the penalty should be posted on the company's bulletin board. The employee's department and occupation should be mentioned but not his name.

Several important factors that offset the need for disciplinary measures in accident prevention might be mentioned in closing this paper, among them an engendering of the spirit of loyalty in the employee to the company; and a development of personal regard in the employee for his job and his employer—they are, after all, his best friends. When it is seen that an employee is properly trained for the work that has been set for him to do, then will have been developed a sense of safety responsibility in that individual employee which will make disciplinary measures unnecessary as far as he is concerned.

Co-operation and education are always better than coercion.

Training of Metermen in Safety Methods

By W. E. Richmond*

Metermen, to be successful in their particular kind of work must have the following qualifications:

1. A high degree of skill.
2. More than usual intelligence.
3. Ability to represent the company fairly in contact with the customer-public.
4. Carefulness in making installations, not to overlook any details affecting safety.
5. Extreme carefulness to avoid possible hazard encountered in their type of work.

As metermen gain skill and experience in their work one of two things happens: they become increasingly careless of accident to themselves, particularly if rushed or overworked, though not neglecting safe installation; or, knowing that the pitcher that goes too often to the well is sure to be broken, they remain, or become, about as careful of their own safety as it is possible for a human being to be while doing such work. Experienced metermen, well acquainted with the possible hazards of their work, may face great risks, but the chance of injury to one who is consistently careful is very small.

Training of metermen in safety methods, then, entails acquainting them with every known hazard of their calling and the requiring of each individual to exercise the utmost care at all times in doing his work. If all the conditions outlined are observed the meterman who has an accident on the job stands convicted of carelessness, though it is admitted that the entirely unexpected happens occasionally. Accidents to metermen are not frequent and when they occur the "wrech, pliers, or screwdriver slipped."

Those concerned with the choosing of men for employment as metermen should consider well the environment and habits of candidates—how they spend their time "off the job"—for their outside lives affect, adversely or otherwise, the safe handling of the details of the work they do for the company that employs them. Metermen shaped to their work along the lines laid down in the foregoing will come near to scoring "100 per cent no accidents."

* Report presented to accident prevention committee.

Hazards of Hydraulic Operation

By J. F. Moran*

We will first consider the hazards in the operation of reservoirs, forebays and canals. One of the first dangers encountered is the leaving of bridges and footways around reservoirs and across canals without proper guard rails, and in high altitude, leaving them covered with ice and sleet, without proper cleaning or protection. The man on the job should keep them free of ice and snow, and they should be constructed in places where spray will not strike them. This should also be considered in the construction of suspension bridges or cables across streams.

The attendants should make inspection of dams and reservoirs, to detect leaks, and regular measurements of water discharged through leaks should be kept as a record, in order to indicate possible failure.

Particular care should also be taken to see that boats used on large reservoirs or lakes are provided with some means to prevent them from sinking, in case they are tipped over. Rafts should not be used where it is possible to have good boats. A safety measure in the use of rafts would be to equip them with ropes hanging over the sides, and with a boathook, so that a person falling overboard might rescue himself or be rescued by one still on the raft.

I believe it would be a good safety measure to install permanent ladders on the inside of lined canals and large flumes, at reasonable distances apart, so that a person falling into such canal or flume would have a chance to climb out.

In connection with ladders, the installation of poor ones, or the omission of ladders entirely where they should be used, and allowing persons to use portable ladders where permanent ladders should be installed, creates a hazard.

After the construction work is done, and the temporary buildings are torn down and the form lumber is taken away, we find nails and scraps of wire generally scattered about. This should be cleaned up as best possible, but there is still the danger of having a few boards with rusty nails, rusty cable, and the rusty form wires protruding from some concrete structure, that are apt to cut or scratch the workman. The precaution should be taught of thoroughly cleansing scratches and cuts and disinfecting them, however slight they may be.

All metal parts of ladders, runways, operating mechanism of gates, etc., should be regularly inspected, cleaned, lubricated, and painted, so as to prevent corrosion and rust.

Next, we will consider the hazards of the operation of tunnels and conduits leading from reservoirs or forebays. The outlet gate or gates that control the water flow into these tunnels or conduits should be of a good design, and special care and precaution should be taken to see that they cannot be accidentally opened by mistake while persons are inspecting the tunnel or conduit. There should be some way to lock them securely open or closed, and any request for movement of this gate or gates should be through one authorized person only. That is, for any specific inspection or job of work, a clearance on conduits or tunnels should be issued to the man directly in charge of the job, and no movement of gates should be made unless the clearance is reported back by this man personally. Do not make clearance system too cumbersome, but make it simple and direct and capable of rigid enforcement. A cumbersome or unwieldy system of clearance becomes objectionable to the parties concerned, and is not rigidly adhered to, being sometimes worse than none at all.

Considering the operation of water wheels in the power plant, the sudden closing of gates or valves may cause dangerous water hammer and burst a wheel cas-

* Report presented to accident prevention committee.

ing or penstock. A positive prevention of the rapid closing or opening of gates or valves should be provided, and also a provision made that these valves can be locked in any position.

During the inspection of a water wheel, the main valves should be securely closed and the operation recorded and a clearance given, as in the case of the gates at reservoirs. It is well to use "Men At Work" signs on the valve control. Do not depend upon the needle nozzle of impulse wheels to stay closed while men are working on the wheel, generator, or in the tailrace. These needle nozzles are for the regulation of the wheel, and when it is taken out of service for inspection or repairs, they should also be taken out of service, and the main valve closed.

Good permanent ladders should be installed in wheel pits where men have to climb in and out, or work on same, as after some use, the lining of wheel pits and the floors become very slippery, and the placing of temporary ladders often gives the workman a bad fall when the ladder slips.

Tightening up bolts in a flange or other fitting while under pressure is a dangerous operation, and should not be allowed if it is possible to do otherwise; but if it has to be done an experienced person who knows danger should do this work.

In some installations a reaction turbine will start a dangerous water hammer, if sufficient air is not admitted to the draft tube to bring the vacuum to a point where the hammering ceases.

Lamp cords used about the power plant for inspection of penstocks, manholes, turbines, etc., should be first-class. In turbine rooms or other places where men may have to depend upon permanent lighting, an auxiliary lighting from storage battery should be provided. Open flames are dangerous on account of explosive gases that are sometimes present.

Hydro-electric plants generally are located in isolated places and operating work becomes monotonous. This tends to make the employees grow careless. The entertainment of these employees should be given consideration as a safety measure. Visitors should be made welcome and encouraged to make trips to these plants. The man up along the flume, forebay, or reservoir is often some distance from any companions, and he should not be forgotten. The operating department should encourage and insist upon entertainment of its employees at plants, and should encourage athletic games, events, etc., which keep a man's mind keen. Substantial encouragement should be given to employees to keep the grounds about the power plant building clean and orderly.

Safety bulletins, if they are of a sane nature and not too gruesome, and are kept clean and neat and changed frequently, help to promote carefulness.

Radio installation should be encouraged, and the operating department should assist the employees in getting first-class equipment at the lowest possible cost, and should encourage and assist employees in the upkeep of this equipment. This is the best means of keeping in touch with the outside world.

Talks on "Safety First Methods" should be given frequently from good broadcasting stations, bearing in mind that they must not be long and must be varied in order to keep up interest.

When it is possible, first-aid teams should be developed and a suitable award made to the winners of competing teams.

Safety Features in Electrical Apparatus From the Manufacturer's Viewpoint

By A. W. Copley*

The electrical manufacturer is primarily interested in manufacturing and selling electrical apparatus and in the development of the electrical art with a view to making it easier and safer to use electric power than other forms of energy. A considerable part of the product of a manufacturer who tries to cover the electrical field is made up of devices for the promotion of safety to the service, equipment and personnel of the operating companies and their customers. Accidents and unusual conditions are bound to occur at times and apparatus must be provided for the protection of these three things—service, equipment and personnel—when such emergencies arise. At the same time extreme precautions should be observed to prevent the occurrence of the emergencies for which safety devices are required. The study of such precautions is the function of this committee.

The causes of injury which must be given special consideration are:

1. Burns from hot metal or flashes.
2. Explosions due to electrical and mechanical forces or to explosive mixtures ignited by an electric spark or arc.
3. Shock—electric, nervous, optical, acoustic.
4. Injuries from moving parts.
5. Unexpected motion in machinery, or parts of equipment.
6. Fires.

Every reasonable precaution must be taken to prevent injuries from such causes as mentioned, but in the application of safety devices discrimination should be used, for safety devices applied to apparatus accessible only to skilled operators may in some cases constitute such a hindrance to efficient and careful work that they are not worth while. On the other hand devices accessible to the general public, or to workmen unfamiliar with electrical equipment, should be fully guarded. Also if it is possible to give the same degree of protection to skilled workmen without undue hindrance to them in their work, it should certainly be done.

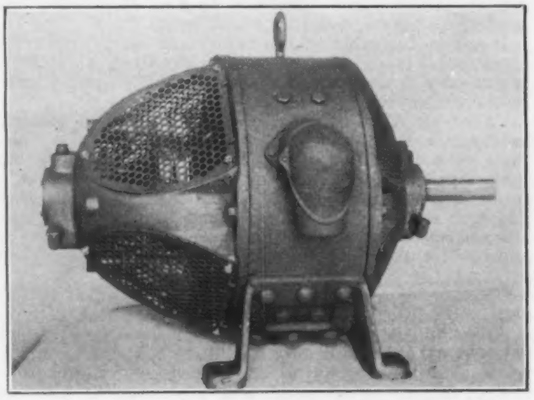

Fig. 1. Semi-enclosed d.c. motor.

It is important that extreme precautions be taken for the prevention of accidents from such apparatus as motors, and many safety features have therefore been embodied in motor design. For d.c. motors the use of semi-enclosing covers has greatly increased in recent years, and the desirability of this type of protection has led to the development of covers by practically all manufacturers of d.c. motors. In order to keep the design of such covers simple and to make them effective in affording excellent protection, and yet readily removable for inspection or repair of the motor, the design of motor brackets has been affected. A motor with

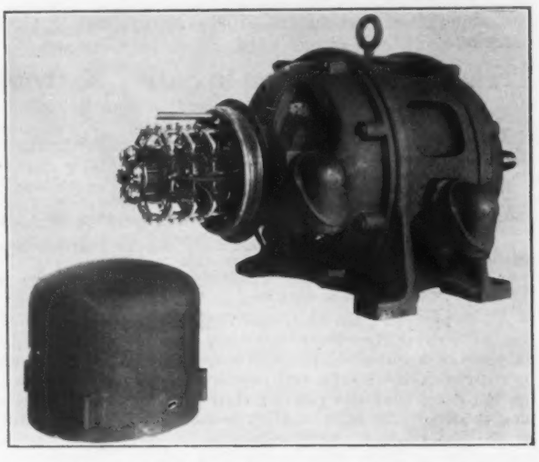

Fig. 2. Enclosed collectors on wound-rotor motor.

* Report presented to accident prevention committee.

brackets arranged for the use of flat punched steel covers is illustrated.

The same kind of development has been made on the brackets of a.c. induction motors so that protective covers can be readily attached, making them either semi-enclosed, totally enclosed or drip-proof.

For wound rotor induction motors, which are to be used in locations where explosive gases, or dust mixtures in the atmosphere may be present, a protective

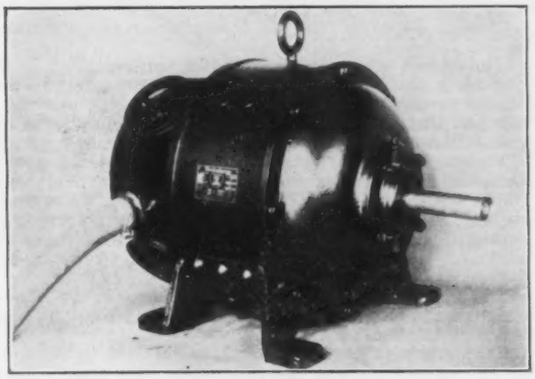

Fig. 3. "Permissible" motor.

covering has been developed for the collector rings which are practically explosion-proof.

The increasing use of conduit wiring has led to motor modifications such that a conduit box can be readily attached to the motor. This construction is now common to practically all industrial motors.

Permissible Equipment

So called permissible equipment is equipment which may be operated safely in locations where explosive mixtures are found, and is equipment which has successfully passed tests made by the Bureau of Mines, which, as a result of years of investigation, research and experiment in the design and use of electrical apparatus in such locations, has formulated rules and regulations to enhance the safety of men and property. There has been a steadily increasing demand for permissible

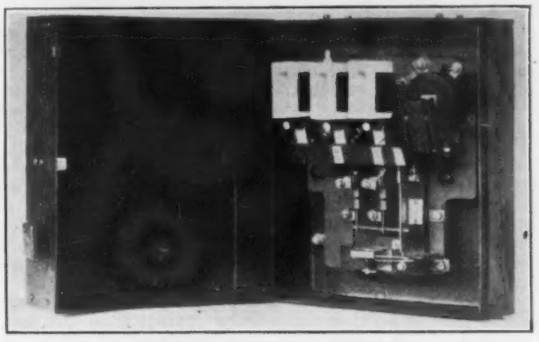

Fig. 4. Line-starter for a.c. motor.

motors and they have been developed in standard sizes up to 20 hp. (d.c.). The end brackets are provided with four screw handhole inspection covers on the commutating end which may be removed to permit inspection and adjustment of the brushes. To guard against these covers being removed by unauthorized persons they are sealed by wire and lead meter seals. The motor leads are brought out through a packing gland in the commutator end-bracket. All joints and contacts are made inside the frame. One of these motors is illustrated.

Apparatus for the control of motors also is often accessible to non-skilled workmen. The tendency of late in the application of control is toward the use of magnetic, or push-button control for all motor equipment. The controller itself is completely housed and all wiring between the push-button controller and motor is in conduit.

Manual starters for d.c. motors are totally enclosed by a cover bolted over the face plate and provided with a lever which permits operation of the starter without exposing the operator to danger of contact with live parts. Starters which are provided with a knife switch, have in addition to the rheostat operating level an external handle for opening and closing of the switch.

Magnetic starters for d.c. motors are made totally enclosed with the covers so designed that their removal leaves the starter parts easily accessible, as shown in the illustration.

For 2,200-volt a.c. manually started motors, extra precautions are provided for in addition to enclosing the starters. In order to protect the operator in case he should close the starter under high short-circuit conditions a steel panel is placed in front of the starter. Such additional protection is not considered necessary for lower voltage equipments.

Magnetic starters for a.c. motors are available in both the air break and oil immersed type. The oil immersed type is particularly designed for use in plants where excessive dirt, gas or acid fumes are present. In these starters all line contacts and the thermal overload relay are immersed in oil so that there is no danger of a spark igniting the surrounding gases.

Permissible equipment is also available in control apparatus for the operation of permissible motors. Such controllers are of the magnetic push-button type enclosed in an explosion-proof case made in two sections.

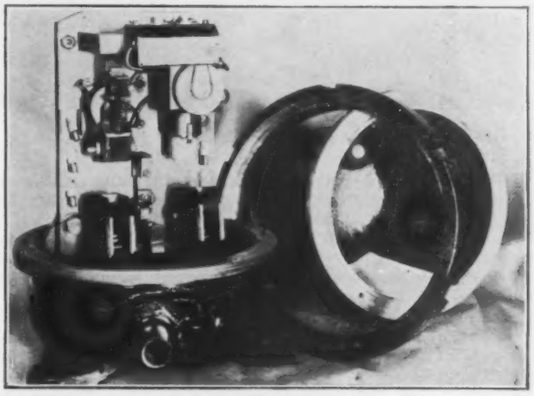

Fig. 5. "Permissible" starter.

The contractor panel is mounted in the base and a top fits over the panel. The fastening of the top to the base must be such that the former can be removed quickly and yet it must be an effective and tight fastening.

Protection of Switching Equipment

Apparatus located in power houses is in general accessible only to authorized experienced men who understand the dangers which are present. It is, however, necessary to so guard such apparatus that accidental, thoughtless or excited action on the part of the operator will be checked. The switching equipment probably constitutes the most serious hazard because in the operation of this equipment the operator is probably more likely to make mistakes than in the operation of other equipment. This equipment must be regularly inspected and it has been the object of manufacturers so to design it that inspection is an entirely safe and simple procedure. Truck type switching equipment has been a big step forward toward this end. Circuit-breakers mounted on trucks are arranged so that the very act of pulling the breaker forward in its cell for inspection purposes disconnects it and isolates it from live parts. Mechanical interlocks make it impossible to pull the breaker forward until it has itself been opened.

Interlocks between breaker and disconnecting switches, between various breakers, between breakers and cell doors and other devices, have been worked out in numerous forms and varieties. Many of them have been devised and installed by the central station men. In the truck type board many of them are incorporated by the manufacturer.

Oil circuit breakers adequately insulated and with grounded frames and tanks are inherently safe as re-

gards shock and burns. Carbon circuit breakers on the other hand are not inherently safe, but must be applied in such a manner that they cannot give rise to injury. They must be mounted high enough to avoid risk of accidental contact with live parts and so that a flash during operation will not be close enough to burn, or injure, the eyes of the operator.

Carbon circuit breakers furnish a good example of a general principle that there is greater hazard in attempting to insulate parts that cannot be adequately insulated than there is in omitting the insulation entirely. There has never been a really dependable insulation devised for interposing between the brush and the frame of a carbon breaker. Manufacturers, therefore, do not try to insulate the brush from the frame. There

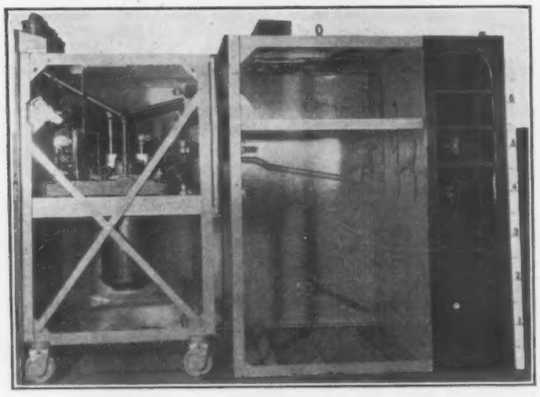

Fig. 6. Truck and enclosing cell for oil circuit breaker.

is less risk in a frame which the operator knows is alive than in one which may be alive but which he believes to be insulated.

Injuries from mechanical sources are minimized by careful planning of the direction and range of motion of operating levers which move suddenly when a breaker trips.

Reverse power protective devices constitute an important protection not only to equipment but to personnel. These guard against a change in the direction of motion due to an inadvertent or unforeseen reversal of power. In the case of elevator motors the desirability of such protection is very evident.

On account of the inflammable character of insulating oil and the possibility of explosive gases being generated from it under certain conditions, precautions are necessary in the construction and installation of all equipment using oil. Arrangements for the safe discharge of gases from the tops of oil circuit breakers such as provided by mufflers and piping from these mufflers to the outside of the building are important. Arrangements for providing safety from the oil hazard in transformers have been given particular attention. The use of an inert gas in the tops of transformers over the surface of the oil not only keeps the oil in first-class condition, but it also provides a compressible space which reduces materially the force of any explosion which might occur under the oil and entirely prevents any secondary explosion above the oil because of the fact that there is no oxygen present to permit such an explosion.

It is impossible to cover in an adequate manner in this limited space the provisions for safety made by manufacturers in their products. The few illustrations given, however, serve to indicate the amount of interest which the manufacturers have in this very important subject. In all design work the question of safety forms a most important item and it is not placed secondary to other matters such as electrical characteristics and performance.

Statistics of Accidents and Accident Causes

By J. M. Buswell*

In an article appearing in the Literary Digest of March 3, 1928, "The Causes Behind Carelessness," Sydney Ingham, safety engineer of the Ludlow, Mass., Manufacturing Associates, in a communication to The Safety Engineer, published in New York, is quoted as saying that few accidents are properly chargeable to carelessness, and that what is generally called by that name may usually be traced to something more fundamental—poor eyesight, alcoholism, late hours, defective nourishment, and so on.

He is quoted further as stating that any safety engineer who is not willing to look behind such a cause as carelessness for an accident, will not get very far toward an intelligent analysis of his problems. "Carelessness," he says, may be a mental or physical condition.

The object of accident statistics, presumably, is to provide a picture of results, so that we can study the causes producing those results and, in turn, form conclusions that will lead us to prevention of accidents by prevention of the causes.

We may use certain statistics as propaganda, but any facts or propaganada must be designed to lead both workers and employers to form conclusions. The most successful arguments must be based on facts, logically arranged straight through from fundamental cause to ultimate result, without omitting any alterable influence.

The final principal effect of an accident is the financial loss and the suffering, perhaps permanent, of the injured man and his family.

Then there is the effect of financial loss to the employer, loss of property or production, loss of efficiency and morale. Tracing back, we find the accident the cause of these effects, and oftentimes attending the accident are supplementary complications which add to the cause or extent of the various effects. So we see how the effects of one accident fan out beyond comprehension.

To know how many accidents of each type have occurred in each department is only one of the major starting points of interest to the executive, while the effects of these (severity and number of each type of injury) represent probably the interest-starting point for the worker himself.

Next, probably, the occupation or operation in which the workers were engaged at time of accident should be considered as a circumstance having a bearing on the problem as it represents an influence or condition entering into the analysis of how accidents occur. To prevent accidents we must know what causes them, and to prevent the recurrence of a certain accident we must remove the thing or condition that caused it—not the instrument but the correctable condition that had most to do with causing the accident.

If an executive cannot or does not eliminate the cause or condition that permits or requires the use of defective tools, for instance, in his shop or plant, he cannot stop the accidents. He may find from his statistics that so many accidents occurred in a certain way in a certain shop through the use of a certain tool. He may find it was defective and remove it, and eliminate all chance of further accidents with that tool. But, if he stops there, the tool that replaces the defective one will begin to be the medium or instrument of more accidents until the executive goes back further and gets at the cause of defective tools being used and corrects that. Then he will have stopped all accidents that may result from that condition.

What does it matter if a man is injured while climbing a pole or setting a meter or operating an air compressor, if the injury was fundamentally due to defective vision? Accidents will always occur to him unless that is corrected, so it is the thing, or condition, that we are most vitally interested in.

Defective lighting, defective supervision, defective health—any one of these may be the fundamental cause of a lot of accidents of many types occurring in many ways, resulting in a variety of kinds of injuries, as well as fire, breakage, loss of production, etc., and these in turn resulting in all kinds of "grief." The removal of one medium or instrument or unsafe practice will only temporarily check a part of that "endless chain." But the nearer we get to the fundamental cause the more effective our prevention will be—the more efficient our efforts.

Fundamental causes are subject to simple and definite correction. Therefore, the most important data is that on fundamental causes. It is surely most startling and instructive to worker, supervisor or executive—the best and most direct and conclusive kind of propaganda; it conforms to the requirements for forming conclusions.

* Report presented to accident prevention committee.

All other data should be regarded as incidental, illustrative of effects or results, proof of existence and extent of original fault.

The most direct way of arriving at or locating these fundamental faults is by tracing back from the individual accidents as they occur, whether these result in injuries or not. This affords quickest conclusions and positive evidence to prove them. It facilitates immediate correction of the particular fault and leads to location of other similar ones and their correction. It is therefore concluded that other statistics are only a measure of failure to find and correct any fundamental faults.

It is because we have not reached these fudamental causes of accidents, at least to a sufficient extent, that the accompanying table is quite incomplete. But let us this year analyze our accidents as they occur, determine the fundamental causes and keep record of them, as well as correct them, and then compare our experiences.

The table includes figures given by six companies. Some gave entire 1927 experience, some apparently classified completely; others classified such as they could at this time. Note that for group X the worker is directly responsible, the company indirectly. For group Y the company is directly responsible, the worker indirectly. For group Z the worker is directly responsible, the company indirectly. For class 9, the company and worker are equally responsible.

TABLE I—Fundamental Causes.

OCCURRED THROUGH	Group "X"			Group "Y"			Group "Z"			
	1	2	3	4	5	6	7	8	9	
A—Failure to use goggles as required	...	...	4	32	11	9	...	...	32	88
B—Failure to use other guards or protectors	...	...	21	3	1	9	...	...	...	34
C—Defective or deficient guards or protectors	...	...	...	...	1	...	...	...	4	5
D—Improper operation of automotive equipment	...	...	5	...	1	16	...	...	17	39
E—Improper operation of machinery or machine tools	...	3	25	3	...	...	1	...	...	32
F—Improper use, handling, and maintenance of hand tools	...	...	79	11	52	19	...	...	6	167
G—Improper construction and use of ladders and scaffolds	...	...	7	2	1	10	...	...	...	20
H—Improper operation or work on electric plant	...	...	17	12	...	17	...	1	10	57
I—Improper procedure involving dangerous gases	...	...	1	6	...	...	...	...	...	7
J—Improper blasting and handling explosives	...	...	...	...	...	...	...	...	...	...
K—An object being allowed or caused to fall from overhead	...	...	75	14	33	47	...	...	103	272
L—Obstructions, improper, on floor, stair, aisle, or suspended	...	...	6	...	3	...	...	...	...	9
M—Falls of person, through own false step, etc., not covered above	5	3	119	22	30	9	2	2	13	205
N—Animal, reptile, or insect attacks	...	...	...	5	...	...	...	...	49	54
O—Poison oak exposure	...	...	...	3	...	...	...	...	21	24
P—Occupational diseases and exposures	4	...	...	...	2	...	...	...	...	6
Q—Improper methods of use, or moving of hot objects, metals, steam, etc.	...	...	13	7	2	1	...	...	20	43
R—Improper methods of use, or moving of other materials or equipment not covered, specifically, above	4	17	110	62	141	26	...	...	1	361
Not classed	48	...	387	20	211	102	4	...	493	1,265
Totals	61	23	869	202	489	265	7	3	769	2,688
Group Totals			1,155			754		10	769	2,688

Causes of Accidents

1. Physical defect or impairment:
   - Missing finger on hand, etc.
   - Sight, hearing, feeling, etc.
   - Stiff joint, lameness, rupture, flat foot.
   - Faulty heart, lungs, kidneys, etc.
   - Other diseases, ill health, or fatigue.
   - Liquor intoxication.
2. Physical deficiency (for the job):
   - Muscularly underdeveloped.
   - Too short, too tall or too heavy.
   - Undernourished.
3. Mental defect or impairment:
   - Worry, grief, hatred, jealousy, fear.
   - Radicalism, bolshevism, etc.
   - Dishonesty, crime, insanity, intemperance.
   - Willfulness, stubbornness, laziness.
   - Fatigue, disinterest, wandering, confusion or distraction, thoughtlessness and carelessness.
4. Mental deficiency (ignorance):
   - Lack of education.
   - Lack of training.
   - Lack of reasoning ability.
   - Lack of ability to absorb instruction.
   - Lack of ability to retain instruction.
   - Lack of courage to demand assistance, protection or instruction.
5. Physical environment, occupational:
   - Repulsive odors or sights.
   - Poisonous gases, fumes, acids or dusts.
   - Defective lighting, heating or ventilating.
   - Repetition of motions resulting in unbalanced muscular development.
   - Especially fatiguing work.
     - (a) hard manual labor
     - (b) constant use of only certain muscles.
   - Insufficiency of help or facilities or guards.
   - Defective tools, equipment or facilities.
6. Psychological environment, occupational:
   - Monotonous noises.
   - Monotonous motion of machinery.
   - Monotonous repetition of mental operations.
   - Fatiguing mental concentration.
   - Job lacking opportunity for promotion or improvement, thereby suppressing ambition and breeding discontent.
   - Improper supervision or instruction, discrimination, favoritism, impatience and intolerance, injustice, oppression.
   - Moral or intellectual inequality of fellows.
   - Improper influence of fellows who may incite bolshevism, hatred, envy, fear, dishonesty or disloyalty by precept, example or ridicule.
   - "Horse-play," joshing," etc.
7. Physical environment in home, etc.:
   - Untidiness, filth or squalor.
   - Unsanitary and unhealthy conditions.
   - Improper food or clothing, etc.
   - Climatic of seasonal discomfort.
   - Home or other off-time labor to excess.
   - Intemperance or immoral habits.
   - Dancing, gambling, etc., to excess.
   - Other social, civic or recreational activities to excess.
8. Psychological environment in home, etc.
   - Illness or affliction in family.
   - Incompatibility and nagging.
   - Financial worries.
   - Dissatisfaction over living conditions.
   - Intemperance and excesses of some member of family.
   - Religious or other intolerance.
   - Lack of sympathetic and inspiring companionship.
   - Unsatisfactory love affair.
   - Improper companions and degrading social relations.
9. Inherent and unavoidable occupational hazards, requiring extreme care:
   - Poison oak.
   - Dog bites.
   - Other animal, insect, and reptile bites.
   - "Hot line" work.
   - Peculiar character of tools.
   - Peculiar character of materials.
   - Peculiar character of equipment.
   - Peculiar character of work.
   - Exposure to hazards or acts of persons not employed or controlled by the company.

Note: No accident ever should be classed in this group unless it is shown that every precaution, guard, or safe practice had been employed and still the accident occurred, in which case it must be considered practically unavoidable.

Training of Hydro Plant Employees in Accident Prevention Work

By H. D. Farnsworth*

Accident prevention has as much importance in the execution of a power house employee's duties as the knowledge of what is to be done. The two are inseparable and as such are taught together.

In the power houses of the Southern California Edison Company the new employee is under the personal supervision of some older employee who is familiar with the equipment and has had sufficient experience to warrant his dependability. In general, a new employee whose age is in the early twenties does not realize the responsibility of his duties and that a mistake might cause thousands of dollars in damage to machinery and possibly an irreparable damage, the loss of life. When he sees a unit brought up to speed and paralleled, or taken off the line and brought to a stop, he probably

* Report presented to accident prevention committee.

thinks that a series of movements is the only difficulty to be mastered and he can learn quickly. He does not realize that enormous forces are involved in such operations, the possibility of tearing a rotor shaft out of its bearings by improper synchronizing and the disastrous results of improperly starting or stopping the flow of water in a penstock. To his mind the meaning of inertia, gravity and kinetic energy apparently have no relation to such operations, and therefore do not make him realize that a "little mistake" can result in large and costly damages.

It is necessary to inculcate in the employee's mind in his early training, responsibility, alertness and care while on duty, and the vital importance of properly executing orders. As he progresses through this period and indicates his capabilities more responsibility is placed on him.

The study and practice of accident prevention and first aid is a duty of every power house employee and the work is co-ordinated under the employees' careful clubs, of which all are members, and of these the chiefs and other responsible men in the stations are designated members. The designated members are the ones who make investigations and organize the work. Their duties are to report and discuss hazards at the monthly meetings, pass judgment on mistakes and accidents and recommend penalities which are passed on to the department head for final judgment and decision. Part of the time at each meeting is devoted to accident prevention and part to first aid. The committee recommends changes or additions that will eliminate or reduce hazards to a minimum and action is taken on the recommendations.

These meetings serve well the purpose of keeping the mind alert and instilling carefulness into the execution of duties.

Safety and Safety Devices in Meter Work

By S. M. Bullis*

The accident prevention committee comes to you gentlemen of the meter committee, not with the thought that you are in the least unmindful of the necessity for safeguards, but with the thought that mutual discussion will be helpful to us all.

Of late years every engineering design has been scrutinized by its designers from the standpoint of safety, as well as from its engineering practicability. There is this distinction, however, in that the engineer incorporates in his design the features which he feels will safeguard against accident. He feels, then, and perhaps rightly, that his work is done. Those in charge of safety and accident prevention know, however, that continual watchfulness, unceasing education, is necessary to keep those safeguards in place and to secure adherence to safe practices.

Sometimes both the worker and those responsible for him feel that too many safety devices and too many safeguards are provided. Probably you all can recall instances and installations where some of the safeguarding was so cumbersome, so planned or placed that it constituted, in itself, a hazard. Such equipment should be so designed that it will not prove unduly irksome to the worker; safe working should be made the natural way of working.

As an instance of the above, rubber gloves, as used in live line work on 2,300 or 4,000-volt lines are cumbersome, but not so cumbersome as to preclude their use in ordinary line or wire operations. However, it is scarcely practicable to ask a man to use them in handling the small bolts, connections, etc., encountered in switchboard or metering work. He will not do it, except under duress. Such gloves are necessary equipment for the meterman, and he must use them in handling line equipment or wires when not otherwise protected, but installations can be designed which minimize the high-voltage handling or heavy current transfers required.

Much, if not all, of the value of accident prevention work is lost if procedures or requirements are introduced which impede the efficiency of the worker. Safety in working positions is rewarded by better speed and greater accuracy. If the meter tester has his attention focused on hazards of his surroundings, he is rather apt to secure less accurate results than are required.

Standardization of installation practices has gone far to promote safety. Skilled workers do not always grow up with and continue their work on one property; they are inclined to shift around. If the practice of one utility is diametrically opposed to that of another, confusion, leading to accident, is introduced into the mind of a man coming on to a property where he has to reverse his habits.

There are meter test devices on the market and in common use, used for shunting out meters on power installations, which do not clearly indicate in themselves the position in which they are left. Indications as to open and closed positions must be positive. Regardless of the fact that the metermen are trained and skilled workers, they are, nevertheless, doing routine work, which in itself dulls the keen sensibilities.

New and permanent installations are installed with adequate space and safeguards; your installation rules indicate careful regard for safety requirements. It is, however, the old installations and the temporary installations where your supervisory attention is needed. Too often temporary installations, as well as most of the old installations, are based on a supposition that a meter tester will perform almost impossible feats of balancing and acrobatic contortions yet keep himself clear of entangling alliances with live wires or equipment. This, then, is a plea for digging into your budgets and standardizing these old installations, bringing them up, together with the temporary ones, to that degree of care which you have so admirably developed for standard installations.

Your installation rules call for separate switches ahead of each meter, but do they specify that this switch be immediately accessible from the meter location? Often the meter is considerably removed from its switch, perhaps in another room, perhaps on the outside of the same wall. Such situations offer temptation to a lone meter tester to handle his test "hot." This often occurs in house installations for architectural reasons, or in power installations for reasons of meter reading accessibility.

The accidents occurring to meter testers and installers are in a large proportion due to flashes. Heavy currents, even at low voltages, are hard to handle. You have developed satisfactory devices to protect the meterman from the hazard of this, the need is to extend their use to all situations. There is often need for two men on a test even at voltages below 440 because of the danger from flashovers when handling heavy currents.

Safety equipment, rubber goods, goggles, fuse handling devices, meter testing blocks, are standardized equipment. Their efficacy depends upon the insistence upon their use which can only come from those in authority. A safety program is no better than the attitude of the departmental management.

We do not, therefore, ask you at this time to adopt new or additional safety devices. We bespeak your cooperation in extending to all situations the facilities you have developed, and to keeping your men keenly alive to the first attribute of all successful work, namely to think, and think first, of safety.

* Report presented to accident prevention committee.

Features of the N.E.L.A. Report on Construction and Operating Hazards of Particular Interest to the P.C.E.A.

By R. T. Richards*

In looking over the N.E.L.A. report on construction and operating hazards, I was impressed with the vast amount of detailed information concerning methods of procedure in accident prevention. All members of the P.C.E.A. can well afford to read the chapters dealing with their particular line of work.

To mention specifically certain definite features of the report of particular interest to the P.C.E.A. is somewhat difficult as it depends entirely upon a personal viewpoint. However, I will mention a few chapters that seem to merit particular attention.

If we are to gain the most from our work in connection with accident prevention, we must, of necessity, make a detailed analysis of our accidents. These records should include all costs, not only wage compensation and medical costs, but incidental property damage losses if sustained. The proper classification and cataloging of accidents and their causes will be of great value in the study of preventive measures to be adopted.

* Report presented to accident prevention committee.

Supervision failure is one of the most important of the various causes listed. It is of the utmost importance that the man issuing orders see that the person receiving the orders understands them perfectly before proceeding to carry them out. Personal carelessness in any form is the foundation of most accidents. To eliminate certain causes that are beyond control, such as abnormal weather, it is advisable to stop all unnecessary work during such time.

The N.E.L.A. report continues with an abundance of detailed information and advice in regard to particular classes of work. Of special interest is the section on station work prior to energizing. An analysis of a large number of accidents indicates that the greater number, though not necessarily the most serious, of construction accidents, occur during early stages of work before system power is applied. Particular emphasis is directed to the need of orderly processes of construction.

Information concerning the proper safety methods to use in initial energizing seems to have been somewhat slighted in previous reports and for that reason it is particularly gratifying to note that considerable data have been included on this important subject. Items such as check of circuits, live test of control circuits, relay settings and test, warning and guards and procedure in applying operating voltage are covered quite thoroughly.

Under the general heading of "Holdoffs" a very complete statement of principles is given and a suggestion made that the method of holdoff outlined in the report be universally adopted. Personally I believe we should adopt such a method for the reason of simplifying operation when new interconnections and joint operation of systems are made.

Line work, including underground and overhead, has been very thoroughly covered and is well worth studying.

The complete report will probably be put out in pamphlet form by the N.E.L.A., and I strongly urge that the sections which apply be placed in the hands of the foremen on the job as it is through their education and training we can expect to decrease materially the number of accidents.

Gas Hazards in Underground Work

By J. R. Rowe*

For the sake of simplicity and understanding in this discussion of gas hazards in underground work I am going to consider the problem under the three main headings of (1) gases and their sources; (2) safe testing for gases; and (3) safe practices for entering and working gaseous manholes.

First, the dangerous gases likely to be found in manholes are under three groups: (1) poisonous gases; (2) suffocating gases; and (3) explosive gases. Poisonous gases and their principal sources are (1) ammonia from refrigerating systems; (2) benzol from motor vehicles and storage tanks; (3) carbon monoxide from manufactured fuel gas, flue gas, exhaust gases from motors and products of cumbustion; (4) gasoline from motor vehicles and storage tanks; (5) hydrogen sulphide from sewer gas; and (6) sulphur dioxide from burning insulation.

The poisonous gases, with the exception of carbon monoxide, are less important as hazards to manhole workers. Ammonia and sulphur dioxide are pungent and irritating so that anyone will avoid them instinctively. Hydrogen sulphide has an odor like that of a rotten egg and is very poisonous but is rarely found in manholes. Benzol and gasoline are readily recognized by their odor.

Natural gas has no poisonous constituents, and respiratory hazards to workers in manholes are comparatively few in cities supplied with this gas but in cities using manufactured gas, leakage into manholes may expose workers to carbon monoxide.

Carbon monoxide is the cause of most of the gassing accidents in manholes as well as in other industrial and domestic life. Manufactured gas contains from 4 per cent carbon monoxide in some cities to as much as 30 per cent in others, so it will be discussed separately at some length here.

Much has been written about carbon monoxide because of its poisonous nature and widespread occurrence. It is odorless except in high concentrations and is tasteless, so there is no way of sensing its presence until the effects are felt and this is often too late. However, fuel gas carrying carbon monoxide usually has a warning odor and many companies in cities using this gas rely upon that odor as their protection against carbon monoxide.

Carbon monoxide when breathed into the lungs combines with the hemoglobin of the blood, thus preventing it from carrying oxygen to the tissues. A concentration of 0.5 per cent will cause unconsciousness in a few minutes, even without preliminary warning. In lower concentrations there are usually some preliminary symptoms such as headache, nausea and weakness. However, these warnings sometimes come too late so that every precaution should be used where there is any danger of carbon monoxide. Four parts of carbon monoxide in 10,000 of air (0.04 per cent) is the maximum concentration that may be breathed for one hour without ill effect. However, because of the cumulative characteristic of carbon monoxide even this small quantity is dangerous if exposure occurs every day, for even a few minutes each time.

The suffocating gases are: (1) carbon dioxide from products of combustion and sewer gas; (2) nitrogen from the same source and natural gas from the gas mains. These are non-poisonous and become dangerous only when present in sufficient amount to dilute the oxygen below 12 or 13 per cent. Suffocating atmospheres are rarely encountered in manholes and the simplest ventilation will overcome them.

The explosive gases are: (1) benzol, (2) carbon monoxide, (3) gasoline from sources named above, (4) ethane from natural gas and manufactured gas, (5) methane from natural or manufactured gas and sewer gas, (6) hydrogen from artificial fuel gases and electrolysis of water. Explosive and inflammable gases constitute the greatest hazard to the underground worker and far more accidents are caused from explosions in unsuspected manholes than from all other gas causes. One of the chief reasons for this is because of the many unsuspected ways that explosive gases may be introduced into a manhole in sufficient quantities to form an explosive mixture. A few of these causes other than those named above are seepage of oil or gasoline fumes from sewers where waste from garages may have been dumped. An explosion recently was traced to this source where the garage was several blocks away. Some waste distillate had been allowed to enter the sewer, and fumes from this had entered the manhole some distance away. Another explosion in a trench was caused by fumes of distillate and oil that had soaked through the sides of the trench from a pit used by an automobile service station to dump old crank case oil and cleaning distillate. The trench in this case ran within about 5 ft. of the pit.

Another uncommon cause of a gas explosion within the experience of the Los Angeles Gas and Electric Corporation was the seepage of natural gas from old oil wells. On the west side of Los Angeles within the last three or four years several new and rather exclusive communities have come into existence on the site of an old oil field. These old wells were, I suppose, pulled and capped several feet below the surface.

We have an underground system in a portion of this territory and the condition now exists where the presence of methane may be found at any time in several of the manholes in percentages from 2 to 10 per cent. The first and only explosion put us on our guard and we probably will have no others as ventilation overcomes the dangerous condition while men are working there. This is mentioned, however, as a warning for any other company that may start an underground system in abandoned oil fields.

Safe Testing for Gases

As has been mentioned in speaking of poisonous gases, all of them except carbon monoxide are quite easily detected by odor. We must rely upon other tests for corbon monoxide, however, and among them a quick test to be made at the manhole is most desirable. There are two of these: palladium chloride test papers and the hoolamite indicator.

The first test may be made by lowering a palladium chloride test paper attached to a string and moistened with saliva into a manhole through a perforation in the cover. After exposure of five minutes the paper is removed. If carbon monoxide is present the yellow color will be changed to gray or black, the amount of change

* Report presented to accident prevention committee.

increasing with the concentration of carbon monoxide. This method is only reliable where concentration is 0.25 per cent or more. For a more accurate, quick, test for smaller concentrations, the hoolamite indicator should be used. This test will indicate as low as 0.1 per cent carbon monoxide. This instrument is on the market so needs no description here other than to say it indicates also by color change, using iodine pentoxide as the chemical to be oxidized. Tests with this instrument can be completed in less than one minute.

Explosive, flammable, and suffocating gases may be dected quite easily and rapidly with a regular mine safety lamp. This lamp lowered or taken into a manhole will, of course, die out in the presence of suffocating gases. Flammable gases will be indicated by a rise in the flame of the lamp and explosive mixtures are indicated by a popping and extinguished flame. This device is on the market in the form of a small lamp and also a lamp of a much larger type. From experience with both I would recommend use of the larger lamp if this type of apparatus is to be used. These lamps indicate flammable mixtures as low as 1.5 per cent, which is far below the lower explosive limit.

A quite efficient apparatus may also be made easily from pipe fittings, pressure gage, spark plug, two electric dry cells, spark coil and switch. This "gas bomb" operates by filling with a sample of air to be tested. Filling is done by use of an aspirator bulb and rubber hose. The filling cock is then closed and the switch turned giving a spark in the bomb. An explosion is registered by a kick on the gage. If there is no explosion then a test for flammability may be made by applying a match to the pet cock as the gas is expelled. Burning of gas at the pet cock indicates a mixture above the upper explosive limits. These are the two dangerous conditions encountered with explosive or flammable gas. If the concentration is below the lower explosive limit there is little danger as long as it remains there.

A condition we have found, however, is that after a manhole or two have been opened, gas sometimes enters after a test has been made and builds the mixture up to one that will explode. The mine safety lamp mentioned above may be used to good advantage under these conditions. It may be hung in the manhole and observed from time to time as the men are working. If gas enters it will be readily indicated in the lamp. These lamps, however, should not be used in the presence of hydrogen or acetylene as they could initiate explosions. Cases of these two gases are so rare, however, that we may consider the flame safety lamp as a safe means of testing for explosive or flammable gases.

Safe Practices in Entering and Working Gaseous Manholes

The following is quoted from the National Electrical Safety Code:

Testing for Gas: Do not enter manholes until you have assured yourself that the manholes are free from dangerous gases by testing with an approved safety lamp, by ventilation, or by other adequate methods.

Also:

Ventilation of manholes may be provided by one or all of the following methods:

1. By hanging a strip of canvas about 2 ft. wide from the top of the manhole guard within the manhole opening in such a manner as to deflect a current of air into the manhole.

2. By removing the covers of adjacent manholes (unless the ducts of the manholes are plugged.)

3. By forcing a current of fresh air into the manhole by means of a blower. The nozzle of the blower hose should be placed near the floor so as to force the gas up and out of the manhole opening.

The whole question of safety from gases in manholes depends upon ventilation and watching for incoming gas after manhole has been entered.

Natural ventilation due to differences in the barometric pressure and wind is often sufficient to keep a hole ventilated when uncovered for some hours and the first two methods mentioned above are effective only under specially favorable conditions. Forced ventilation is the only method dependable under all circumstances. Of course it goes without saying that where there is definite leakage of gas into a manhole, the source should be detected, if possible, and stopped. Any time the leakage is constant there is danger of an explosion even with forced ventilation as the explosive range of a methane and air mixture is from 4.5 per cent to 14 per cent.

In closing a general discussion of gas hazards, it is well to mention two more important items. These are the importance of odor and first aid for gassed workers.

Foreign odors in manholes are important indicators of the pressure of noxious gas. An earthy or musty odor usually pervades manholes, and nearly all harmful gases, as has been mentioned, have a warning odor with the exception of carbon monoxide. The odor of tar or creosote is sometimes mistaken for that of gas but it is a good safe procedure to investigate thoroughly and ventilate every hole having a foreign odor.

Regarding first aid for gassed workers, all underground or manhole workers should be thoroughly trained in the principles and practice of the prone pressure method of artificial respiration, especially as the same method is used in resuscitating a man overcome by electric shock.

Operating Personnel*

The skeleton of subjects upon which was based the past year's work of this subcommittee is as follows: (1) Selection of employees—methods, standards required, age limits, physical condition, mental attitude, experience, education, and investigation of references. (2) Training—plan of organization (if any), methods, apprentice system, etc. (3) Operating organization—inter-relationship of such functions as operation of generating stations, substations, transmission stations, distribution stations, shop testing, maintenance work, etc., and handling methods as to over-time work. (4) Discipline—penalties, bonuses, etc., merit and demerit systems. (5) Personnel records—service records, advancement records, general progress, etc. (6) Promotion—seniority system, merit-and-ability system, frequency of promotion, basis for promotions, etc.

Of twelve requests for reports from member companies based upon the above outline, nine were received. A digest of these follows:

1. Selection of Employees

All companies require that the applicant fill out an application blank, take a physical examination, and the employer interviews the applicant for the purpose of forming an opinion of his mental attitude and ability to hold the position for which he is applying. Although there is some variation in the method and means employed the aim is the same, which might be summed up in the question: "Will the applicant be an asset or a liability"? Young men are preferred to older men, ages from 20 to 25 seeming to be most common. One company sets the employment age limits at not under 10 nor over 50.

Several reports mention the desirability of the applicant having completed high school although none seems to place especially great stress on the desirability of the applicant being a college graduate. All mention the desirability of experience although some point out the fact that the man with previous experience has to make a more strenuous effort to fit into his new job than does the apprentice on account of the human tendency to look backward to the old methods left behind instead of forward to the accomplishment of the desired result by efficient use of the methods employed by the new organization around him.

Investigation of references seems to be quite generally followed up by the employment or personnel departments of all the companies, although more stress seems to be laid on the verifying of the truth of the applicant's statements, than upon the usefulness of the recommendations involved.

2. Training

Training seems to be left largely to the discretion of the immediate superior officer in each case, rather than through regularly organized channels. Some companies reported the use of questionnaires, some of which apparently have been expanded to cover the field pretty thoroughly, the credits for completion of which are kept on record cards and considered when promotion is in order.

It is believed that the future demand for better trained men will require more definite and better organized attention to this point, both in selection of new men and the fitting of old employees for more responsibility.

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* Report of subcommittee of accident prevention committee—A. P. Sessions, chairman. K. B. Ayres, C. F. Benham, W. S. Boggs, H. H. Cox, R. S. Daniels, R. C. Denny, C. Kirtley, P. J. Ost, Clark Pettingill, A. E. Strong

3. Operating Organization

Operating organization shows considerable variation in the naming of sub-department groups, but the functional grouping is largely the same. Most companies have their maintenance work carried out separately from the operating group. It is notable, however, that one company successfully has combined the function of routine maintenance with that of operating, so that all normal maintenance work is carried out by the operating organization with the result that this company has been able to reduce maintenance costs very materially while greater incentive and opportunity for growth is held out to the operators at the same time by so doing.

4. Discipline

Discipline, as such, does not seem to be very generally followed, although some report the application of reprimands, lay-offs, etc. for cases of carelessness. It seems to be the general consensus of opinion that normally a man learns more caution on account of a mistake and consequently is less likely to repeat the same experience than is a new man. Therefore, none reports discharging men for mistakes, except as repeated errors may indicate dangerous tendencies or continued gross carelessness.

5. Personnel Records

Personnel records of some sort are kept by all companies reporting, although the use and application, as well as the extent to which they are developed varies greatly. Some use a rating system as the basis for promotion. Others use a rating system as a guide only, recognizing the fact that men, conditions, and requirements, vary more than a percentage figure will indicate.

One report contains description of a rating system based upon ten general qualifications as follows: trustworthiness, carefulness, industry, initiative, co-operation, tact, neatness, intellect, knowledge, and management.

Promotion in most companies seems to be upon the basis of merit and ability, although the means of applying this measuring stick vary widely. Some companies give considerably more weight to seniority than others, while some report that the idea of seniority has been abandoned almost entirely. The common ground between these two extremes seems to be the aim of most concerns, where promotion is made with attention to superior ability, but giving the benefit of any doubts to the older man in the service, where other things are about equal.

It is believed that more concentrated attention to the intelligent measurement of the abilities of men in the future by all companies will be productive of very great returns.

Two things to-day stand out prominently as great obstacles to more perfect service in the power business. One of these is the lack of perfection in relay design and application. The other is the imperfection in the men who are building and handling the equipment.

It is urged that this subject be continued in the future and that all companies give their "personnel" problems more conscious study to the end that each may benefit by learning of the experiences and accomplishments of the other. A definite suggestion for next year's studies along this line is this: practical interest will be stimulated and much usable material brought out if each company be asked to contribute a thorough description of what they consider their best effort along the lines of measurement and improvement of their personnel.

This year, the object has been to make a general survey and establish a ground work. Future years should place before all, the details, methods, and results from the most successful experiments which may have been carried out by the various members of the P.C.E.A. Through the scramble for greater accomplishment and the establishing of "better service," the industry is realizing more and more the truth of Emerson's statement, that "a monument is not greater than the hands that shaped it."

Electrical Apparatus Committee Reports[2]

In handling the subject of transformers and regulators the committee gave special attention to the problems of:

Selecting the proper type and size of transformer for a given location.

Maintenance of transformers under service conditions.

Use of tap-changing equipment at system interconnection points and at important distribution centers.

A study of recent developments and improvements in design and manufacture also was included in the year's work. In dealing with the subject of induction regulators the matter of protecting against short-circuits, by reactors or otherwise, was stressed.

The subject of oil circuit breakers was treated under the headings of manufacture, application, and operation. One objective of the committee in handling this subject has been to co-ordinate the views of the operating men with those of the manufacturer so that both may be aided in handling their respective problems.

The rapid development in the manufacture and application of relays makes this a subject worthy of the attention it has received by the committee in this year's program. New types and new applications are of extreme interest to all operating companies and much valuable information has been collected from the contributing members concerning the reliability and performance of various relays under abnormal conditions.

The study of the lightning arrester problem as applied to the area represented by the committee membership disclosed much interesting information concerning the practice of the various operating companies in regard to lightning protection. Data submitted discloses the fact that there are certain localities in the Pacific Coast territory studied where lightning is quite prevalent, notwithstanding a popular belief that this area is immune to such disturbances.

By reason of the increase in size of generating units and transformers it was considered that the subject of fire protection should be included in the committee's program this year since the greater concentration of kva. capacity in individual pieces of equipment makes the protection of the apparatus against fire loss all the more important. The committee has attempted to include all new installations and report on the operation of existing fire-protective equipment in its review of this subject.

A very interesting report resulted from the inclusion of the rather special subject of load dispatching in the program for the year. This report, in addition to dealing with the functions of the system load dispatcher, points out the advantages to be gained by increasing the activities of the dispatcher's office.

The study of the subject of operating personnel disclosed the fact that there is a marked lack of uniformity in the handling of the personnel problem. This subject undoubtedly is worthy of more attention on the part of all operating companies, as is pointed out by the report of the subcommittee.

In including the subject of Operating Methods, Routine and Experiences in the year's program the committee had in mind the benefit that would result from the exchange of information relative to operating practice. The treatment of this subject naturally contained much detail and is rather broad in its scope.

Because of the importance attached to the study of

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utilization equipment by the N.E.L.A. apparatus committee some attention was given to it by the corresponding committee in the P.C.E.A., but because of the fact that the subject was not taken up until the middle of the committee year, and the necessary investigations were not completed, it is considered unwise to include it in this year's report. The subject has been recommended to next year's committee for further study.

Relays and Relay Applications*

The following program was submitted for consideration this year:

Program

1. New types of relays, with special attention to carrier current relay applications.
   (a) Manufacturers' reports of new types of relays or improvements in old relays.
   (b) Operating companies' report of experience with use of carrier current for relaying or control use.
2. New applications of relays, with special attention to residual or ground relay applications.
   (a) Any new applications of relays.
   (b) Use of residual relays to protect radial lines, parallel lines, loop systems, net works (high voltage). Describe applications and settings of current and time in each case.
3. Report of operating experiences. If possible, report of relay operations, showing causes of imperfect operations.

The companies on the Pacific Coast are not as yet greatly interested in carrier current relays, but have turned their attention to the wider application of residual relays.

New Types of Relays

The following advantages are claimed for a carrier current pilot system of transmission line protection:

1. The employment of potential transformers will be avoided.

2. The scheme should not require any definitely quantitative function on the part of the carrier apparatus since there may be variations in attenuation.

3. There should be no apparatus installed as part of the protective system which in itself represents an extension of the liability to trouble of the circuit protected. Current transformers of high safety factor, preferably of the bushing type, should be used. The carrier-current coupling equipment should be of the most reliable form available.

4. The equipment, so far as possible, should be entirely current operated; that is, its operating power should be derived directly from the fault current.

5. Failure of the carrier-current apparatus should not render it possible for a fault to remain on the line, thus disturbing the whole power system. Rather such a defect should advertise its presence by causing only the individual line to trip unnecessarily if overloaded.

6. The system should be suitable without modification for installation at any point in a network irrespective of possible direction of flow of fault current, etc.

7. It should be possible to check the carrier-current equipment at any time without interfering with service.

8. In view of the fact that a restricted range of frequency is assigned to control systems only one frequency per line protected should be used.

In conclusion it is said that this system will furnish protection substantially equivalent to that which may be obtained with a pilot wire system, provided that the lowest phase-fault current at which it is desired to operate is not less than the normal rated current of the line. In the case of ground faults, it is possible to obtain operation at lower values than full-load current.

Tests have been made on a 66-kv. line about 30 miles in length. The apparatus was excited from standard bushing transformers. Actual short circuits, both between phases and to ground, were applied to the line itself or at neighboring locations. The system performed satisfactorily with fault currents which ranged from 200 to 1,700 amp.

Directional Over-Current Relays

The type "CRC" directional over-current relay is for ground protection on a grounded neutral system. It can be applied to high voltage systems where the burden on a bushing type potential device must be reduced to a minimum or to systems where there are no potential transformers available. Instead of securing the directional feature from the phase relation of a residual current of the line to be protected and the residual voltage, both of the windings on the directional element have a current coil. The residual current of the line is applied to one of these and the residual current of a power transformer bank is applied to the other. Since these currents are very nearly in phase, it is possible to secure correct operation of the directional element on the system during a fault. As the relay is connected only in the residual circuits of current transformers where there are no currents under normal conditions, the relay settings may be made for much lower values than the normal full load currents.

Where switchboard space is limited, or for some other reason it is undesirable to use three single-phase "CO" relays, they call attention to their Type "CO" three-phase relay.

These relays, consisting of three single-phase induction elements mounted in a single case, are similar to the three-phase "COA" relays, but are supplied without the current indicating vanes or the supervisory trip

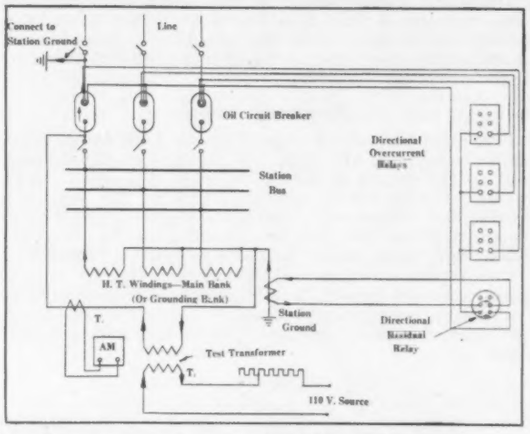

Fig. 1. Directional check of directional residual relays—Case I.

circuit. They are used to trip only one circuit breaker but can be supplied with a three-point contactor switch, the third point to be used for a bell alarm circuit.

Impedance Relays

The most recent form of impedance (distance) relay is the Type "CZ" duplex impedance relay. As the name implies, each duplex relay is in itself equivalent to two of the single-element Type "CZ" relays, being composed of two voltage restraining elements operated by a single over-current unit. The duplex relay is intended for applications where both line and ground protection are desired and the space is limited. For the complete (both line and ground) protection of a single three-phase line, only three duplex relays are required at each end of the section of a line, instead of six as in the case of the single element relay. The application of the duplex relay is limited to such transmission lines as yield fault currents no less than 200 per cent of the current tap setting of the relay and the shortest single section of line to which they can be applied must have a voltage drop of at least 4.5 per cent of normal (110 volts), that is, 5-volt secondary on the line voltage element and 2.9 volts on the ground voltage element, at the time when the minimum permissible current above mentioned is flowing.

Directional Residual Relays

The "CWC" directional residual relay has been designed for ground protection on systems operating with grounded neutral. Its application does not require the use of potential transformers to secure directional control. This relay differs from the usual directional relay as instead of depending on a separate directional element operating on the phase relation of the current and voltage, the directional feature is incorporated in the relay by taking advantage of the relative direction in which the residual currents flow in the lines to be protected and in the power transformer bank neutral. The relay has two current windings, one of which is connected in the secondary residual current circuits of the line current transformers, while the other is connected in the secondary of the current transformer

* Report of subcommittee of electrical apparatus committee—L. A. Buese, chairman. J. C. Albert, Frank Ayres, R. C. Denny, P. B. Garrett, Chris Goldkamp, A. J. Hall, H. S. Lane, W. E. Melarkey, J. H. Vivian, G. H. Whitney.

in the neutral of the power transformer bank. In case there is no transformer bank, a representative current may be obtained from an artificial grounding bank of potential transformers. The phase relation between the residual current applied to the relay is such that faulty operation on the directional control is impossible and the induction element will not rotate in the tripping direction unless the fault is on a line which the relay is protecting.

The relay has an operating current which is inverse to the product of the current in the two windings. The magnitude of both of these currents is proportional to the distance from the fault so that for ground faults close to the station both of the residual currents are relatively high and the relay will operate quickly. Where the fault is at a considerable distance from the station the distribution of ground current is such that the product of the residual current is low. By proper selection of the current taps and current transformer ratio in the transformer bank neutral the relays may

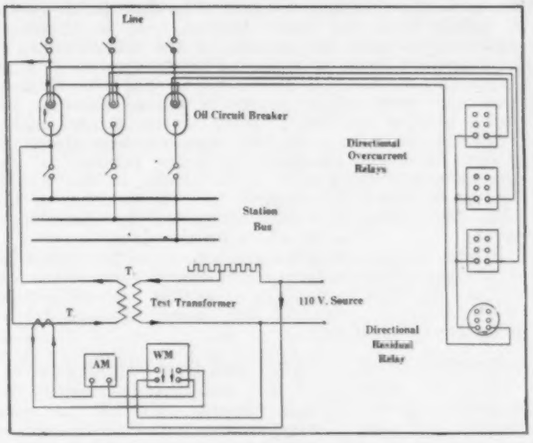

Fig. 2. Directional check of directional residual relays—Case II.

be set selectively to clear faults within a given section of the transmission line. Since the residual currents are used in the relay rather than the line currents, operation may be secured even though the fault current is less than the normal full load current.

New Applications of Relays

A large amount of attention is being given to residual relays and tests of directional residual relays.

Under this heading the Pacific Gas and Electric Company submit a very interesting and complete report which is as follows:

Direction Check of Directional Residual Relays

Whenever feasible it is perferable to check directional residual relays by actually grounding the controlled line and building up with a generator, so as to determine definitely both the direction and time current setting for actual operating conditions.

Frequently this is impracticable or inconvenient, particularly at the time of cutting in new construction. While it is possible to determine correctly the connections of a directional residual relay for the desired direction of operation, given complete and accurate knowledge of the station power and instrument wiring and polarities of all transformers involved, this is advisable only as an emergency or temporary measure.

Consequently the following methods for checking such relay installations in the field have been developed and used by the department of electrical construction and operation. These tests give a positive check of the directional feature and in certain cases, as noted, give a relative idea of the time current setting of the relay under actual operating conditions.

The three applications of the directional residual relay as regards method of supply for the directional element are treated separately as Cases I, II, and III following:

Case I. Relay residual current element supplied by residual from line current transformers, directional element supplied by current transformer in grounded neutral of main transformer bank (or of grounding bank connected to delta system).

Assuming that it is desired to trip the breaker for phase to ground faults on the line beyond the station equipment, and knowing that for an instantaneous value of line current outgoing to the line the current in the bank neutral will be from ground to bank, it is only necessary to pass current through the neutral current transformer and one line current transformer in series, as shown in accompanying diagram, Fig. 1, connecting the loads to the directional residual relay so as to close its contacts. The ammeter and timing device are used in the usual manner to determine the relay current and time setting, which will be approximately correct for actual operating conditions.

In this test it is not necessary to know the polarity of the test current or of the current transformers, provided that it is determined in the usual manner that the line current transformers are correctly connected to furnish zero residual at balanced three-phase load. Only one phase need be tested for direction.

Case II. Relay residual current element supplied by residual from line current transformers, directional element connected in the secondary delta of star-delta bank supplied from bus potentials.

Consider the general case of a star-delta bank connected to a star grounded system. If the voltage on one phase is reduced, as by a phase-to-ground fault on the line, then the current will be generated in the transformer of that phase and consequently flow in the delta in such phase relation and amount as to tend to restore the voltage in the phase involved in the fault to normal, namely, in the same phase relation as the normal or fault current in that phase. That is, if the instantaneous value of current in the faulty phase is from the station to the line, the so-called circulating current in the delta and the fault current in the line and in the residual element of the relay will be in the same phase relation or direction, considering the polarities of the transformers involved.

This test therefore consists in simulating in the relay circuits the conditions of a line fault to ground on one phase by artificially reducing the voltage of the same phase of the star-delta relay directional bank in the manner described below.

It is first necessary to determine the direction of current flow in the lower or residual current element of the relay when the instantaneous direction of current through the circuit breaker is toward the line. The first step in this determination is shown in Fig. 2. Current from any single-phase source is passed through one phase of the circuit breaker by means of the testing transformer. By means of the current transformer T2 of known polarity this current is supplied to the current coil of the single phase wattmeter in known direction in relation to the current through the breaker. The wattmeter potential coil is then connected so as to give a positive reading of the wattmeter. Without disturbing the potential connec-

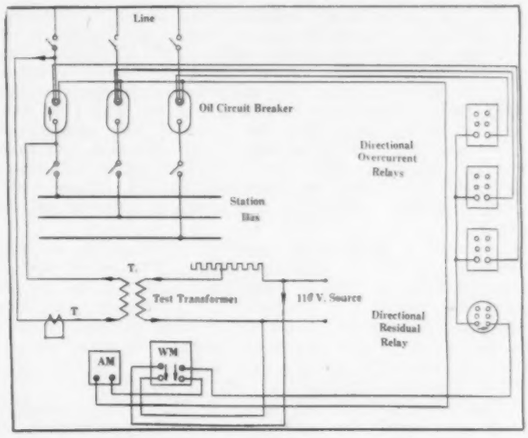

Fig. 3. Directional check of directional residual relays—Case II, meter current elements in series with relay current elements.

tion of the wattmeter or the circuit through the circuit breaker the current element of the wattmeter is cut in series with the residual current element of the relay as shown in Fig. 3 in such a manner that with current through the breaker as before the wattmeter

shows a positive reading. This now enables the direction of current in this relay coil corresponding to instantaneous value of current, assumed outgoing to the line, to be traced, and to be marked for future reference.

The next step is to determine the connection of the directional element to cause the relay to close its contacts for instantaneous value of current outgoing to the line. This is accomplished as shown in Fig.4. Using one bus potential transformer for the source for potential and current for the wattmeter, pass the current through the wattmeter and the residual element of the relay so that the instantaneous direction corresponds to instantaneous outgoing line fault current as determined in previous check, Fig. 3. The

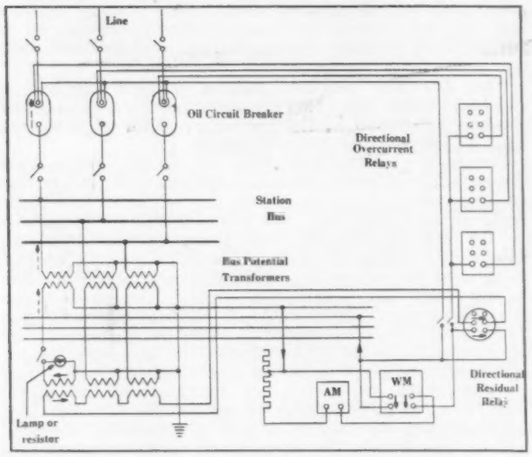

Fig. 4. Directional check of directional residual relays—Case II.

effect, within the delta connected to the directional element of the relay of a fault-to-ground on the same phase, is now simulated by disconnecting the primary of the neutral relay transformer on that phase and shorting it through a lamp or other resistance, which will cause current to flow in the delta in phase with the current in the residual element of the relay. The leads to the upper or directional element of the relay now may be connected so as to cause its contacts to close. The amount of current in the delta may be controlled by varying the resistance in the short circuited primary, and the current in the lower element may be adjusted (within the capacity of the potential transformer) so as to obtain a time current setting roughly corresponding to the actual operating conditions.

In this case it is necessary to know the polarity of the bus potential transformer, as indicated by arrows for instantaneous values of current in the figure. It is not necessary to know the polarity of the line current or neutral relay transformers, provided that it is determined in the usual manner that they are correctly connected for normal load conditions. Only one phase need be tested for direction. It is of course essential that the relay transformer whose primary is shorted is connected to the phase which furnishes the current in the residual element of the relay.

The above method is used where there is no convenient source of sufficient tripping current for an overall test or where complete information is not available as to the transformer polarities and consequent phase relation of the testing current relative to the primary line current. It has the disadvantage of involving considerable time and care and requiring three separate operations for its completion.

The following method, shown in Fig. 5, has therefore been developed for use where it is practicable to make an overall test. In this case it is necessary to know the polarities of the test transformer T1 and of the station bank or other transformers involved in furnishing the test current, so that current may be passed through one element of the oil circuit breaker which will be in phase with that line phase voltage, that is, whose instantaneous direction through the breaker will be toward the line when the instantaneous direction of the line load current is outgoing as indicated by the arrows in Fig. 5. This current through the breaker will of course give a resultant in the residual element of the relay corresponding to the residual due to a line-fault current. Current in the relay delta simulating that due to the fault is now produced by disconnecting and shorting the primary of the neutral relay transformer in the same phase as the test current through the breaker, whereupon the connections to the directional element of the relay are made so as to close its contacts.

In this test it is not necessary to know the polarities of the line current transformers, bus potential transformers, or neutral relay transformers. An approximate time current setting of the relay may be obtained as in the previous test.

Case III. Relay residual current element supplied by residual from line current transformers, directional element supplied from current transformer in delta secondary winding of any star-delta bank connected to the system.

As explained under Case II, a fault to ground on the system will cause a current to flow in the delta in phase with the fault current. It is therefore necessary to know the polarity of the transformers of the star-delta bank, as indicated by the arrows showing instantaneous current directions in Fig. 6. Current from any single-phase source is passed through the circuit breaker and the primary of the current transformer in the delta so that the instantaneous directions of current in the breaker and in the primary of the current transformer will be as shown in the figure. Current will then be supplied to both elements of the relay simulating fault conditions, and the connections can be made so as to close its contacts.

In this test it is not necessary to know the polarities of the current transformers in the line or delta, nor of the test transformer T1. The time current setting of the relay under actual line fault conditions is not indicated by this test.

Direction Check of Directional Overcurrent Relays

It is the practice of this company to connect the respective potential and current coils of the watt element in phase. Owing to the fact that the relays will reverse due to low lagging power factor, it is frequently impossible to check definitely the direction of operation by observing their action in service on a loaded line. While it is possible to determine correctly the connections of such a relay for the desired direction of operation, given complete and accurate knowledge of the station power and instrument wiring and the polarities of all transformers involved, this is advisable only as a temporary or

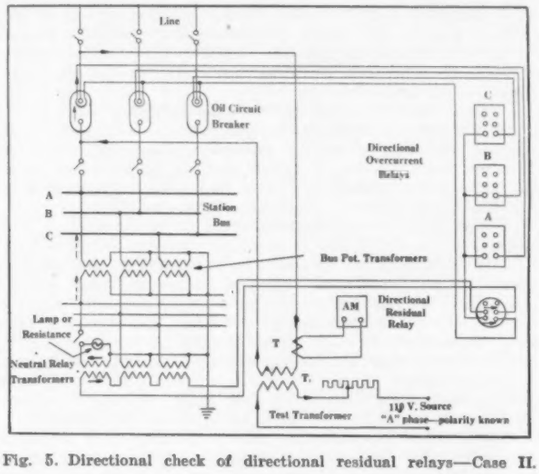

Fig. 5. Directional check of directional residual relays—Case II.

emergency measure. Consequently the following method for positively checking the direction of operation in the field has been developed and used by the department of electrical construction and operation of this company:

It must first be determined that the current and potential coils of the relay in each phase are connected to the current and potential transformers of that phase. The polarity of the potential transformers must be known, and also the polarity of the 110/10 volt testing transformer.

The accompanying diagram shows the test connections. Each phase must be tested for direction separately. The 110-volt winding of the test transformer T1 is energized from the potential transformer supplying the relay. Assuming that it is desired to trip the

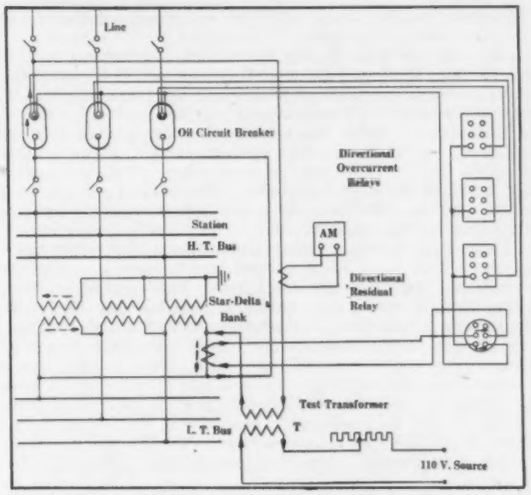

Fig. 6. Directional check of directional residual relays—Case III.

breaker for vaults on the line, the secondary of the test transformer is connected to the circuit breaker in the corresponding phase as shown so that when the instantaneous direction of the current in the potential transformer is from the bus to the transformer the instantaneous direction of current through the breaker is from bus to line. The watt element contacts of the relay should then close.

It is necessary, of course, that the current taken from the potential transformer be limited to its capacity.

The Southern Sierras Power Company submits a diagram of their San Bernardino substation and its relay protection.

The general scheme of relay setting for these lines at San Bernardino is as follows:

The 33-kv. ground bank is provided with overload protection and has a sensitive ground relay inserted in the secondary of a saturated core type current transformer in the grounded neutral lead. This sensitive relay in the ground bank neutral is given a very low setting so that it will respond to a very light ground on any 33-kv. line. The only purpose of this relay is to sound an alarm to notify the operator that a ground exists on the system. By referring to the switchboard instruments, the operator can determine which line is grounded and the severity of the ground. Because so many grounds are of a slight or intermittent nature which do not prove dangerous and very often are self-clearing, the ground relays on all 33-kv. lines are not set low enough to respond to such faults. The overload protection relays on the ground bank are set to operate with a minimum primary current of approximately 100 amp. All ground relays are set to respond to a lower value of current than this to insure the ground bank remaining in service to clear line grounds.

The San Joaquin Light & Power Corporation makes no use of ground or residual relays. It thinks that the new directional residual relays are hardly justified on a system where directional relays already exist. As has been reported for several years, this company uses single-phase directional over-current relays for protection of its transmission lines in connection with bushing type current transformers in the switches. There are probably not over 375 of these in service on the looped lines. The current setting or tap values are graded both ways in each loop as well as the time values or lever settings. Parallel lines are protected by duo-directional over-current relays, the current elements connected across the differential connections of the current transformers in the two lines. Blocking relays are provided in the trip circuits of the two switches which are solenoid relays of the instantaneous opening and time delay closing type. In this way the tripping of one switch blocks the other till the switch at the far end has operated and the system settled down from the disturbance. The closing time of the blocking relay may be on the order of 10 sec., after which the switch on the remaining good line becomes automatic. The current setting on such relay protection is about five times normal load current and the time kept down to the one index setting or half that on low energy, geared relays.

Considerable interest is being given bus protection. Companies reporting use of differential connection of current transformers for bus protection include Bureau of Power & Light of the City of Los Angeles, Southern California Edison Company, San Joaquin Light &

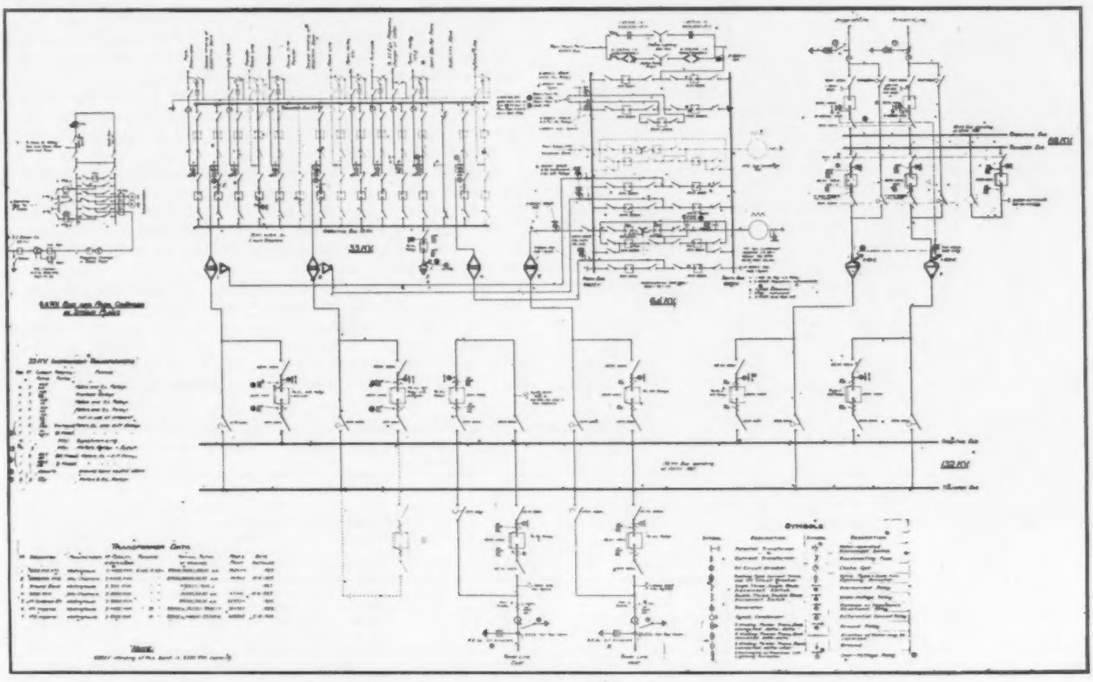

Fig. 7. Single line wiring diagram of San Bernardino substation extension of 1927.

Power Corporation and Los Angeles Gas and Electric Corporation.

The Los Angeles Gas & Electric Corporation reports successful tests on a bus protection scheme in which the pipe work supporting the bus is grounded through a current transformer. This current transformer is connected to a multi-contact relay which trips the breakers connected to this bus.

The resistance of ordinary concrete is the only insulating medium used between steel work supporting buses in double bus substations.

Report of Operating Experiences

The Bureau of Power & Light of the City of Los Angeles submits a report of operating experience with protection relay equipment.

The period covered by this report is three years, beginning October, 1924. At that time the 33-kv. network was protected almost entirely by definite time overcurrent relays. Since that time, however, these have all been replaced by the most modern type of protective relay. At the present time the system is comprised of the following protected equipment:

2	110-kv. transmission lines. Total of 90 miles.
66	33-kv. transmission lines. Total of 325 miles.
6	33-kv. underground cables. Total of 13 miles.
17	33-kv. buses.
45	transformer banks. Total of 185,300 kva.
6	synchronous condensers. Total of 50,000 kva.
9	motor generator sets. Total of 7,800 kva.
217	2.2 and 4.4-kv. feeders.

The following table gives the number and type of various relays used on the system:

Over-current relays	913
Directional over-current relays	72
Directional impedance relays	72
Selective differential current relays	49
Ratio differential relays	33
Current differential relays (pilot wire)	6
Auxiliary relays	355

The following table classifies the protection according to apparatus protected and gives cases of trouble and relay operations:

Apparatus	Number of Cases of Trouble	Correct Relay Operation	Incorrect or Excess Relay Operation	Failed to Relay
110-kv. transmission lines	19	17	2	0
33-kv. transmission lines	327	275	51	1
33-kv. underground cable	2	2	0	0
33-kv. buses	2	2	0	0
transformer banks	21	21	0	0
synchronous condensers	2	2	0	0
motor generators	0	0	0	0
Total for 33-kv. and 110-kv.	373	319	53	1
2.2 and 4.4-kv. feeders	1,575	1,575	0	0

The above failure was caused by a faulty pallet switch on one of the oil circuit breakers which made the trip circuit inoperative. The incorrect or excess operations were caused by conditions such as incorrect settings, relays out of calibration, system surges, improper application and obsolete relays. Most of these conditions occurred during the period in which the relay system was being installed and it was hardly possible to keep proper protection and settings all of the time.

In most of the cases of incorrect or excess operations no load was lost and there were no outages to the consumer.

From the above operating experience it seems that failure of relay protection occurs in the operating circuits rather than in the relay itself. Also that incorrect operation is more common than failure of operation. Constant supervision, test and inspection will hold the number of failures and incorrect or excess operations to a minimum. Inspection and test of operating circuits is of as much importance as the inspection and test of the relay itself.

The Pacific Gas and Electric Company submits the following report and analysis of relay operation on its high-tension system.

The information in the accompanying table covering the period 1923 to 1927 and the manner of its compilation would seem to be of practical interest, consequently the explanation of the analysis is given in full below:

Column 1. Total Operations Involving Relays. All cases of trouble on the system which investigation showed involved the relays in service. This comprises the total of the other columns. (Note: Relay operations due to accidental shorting or closing of contacts are not included in this tabulation.)

Column 2. Correct Relay Operations. All relay operations which have been proved to be correct under the conditions existing at the time. This includes many cases which were not entirely satisfactory from an operating standpoint, but where, owing to load, voltage, and power factor conditions, it was necessary to credit the relays with correct operation, considering their connections and settings. There are also included here a number of cases where unsatisfactory relay operation occurred due to inadequate equipment. (See also columns 5 and 6.) In all cases, however, the relays themselves functioned correctly considering the circumstances.

Column 3. Relay Failures Due to Relay. All cases where subsequent investigation has proved that conditions at the point in question were such as to permit correct relay operation, but the relays themselves failed to function and the switch did not operate. Prior to 1925 investigations were not conducted with the same thoroughness and experience as in more recent years and in many cases failure of the switch to operate was charged to the relays when under the present methods of investigation it would have been shown that the load or other system conditions at the time of the trouble did not call for operation of the relays, considering their time and current settings, or that the failure was due to other external causes such as faults in wiring or auxiliaries.

Column 4. Relay Failures Due to External Causes. All cases of failure of switch to operate where subsequent investigation proved the failure to be due to break, ground, or other fault in the wiring, auxiliaries, or switch external to the relays themselves, or to power factor or other system conditions. Prior to 1925 these cases were not segregated in the tabulation.

Column 5. Incorrect Relay Operations Due to Relay. All cases of switch operation that have been proved by subsequent investigation and test to be due to faults, either mechanical or electrical, in the relays themselves. (Note: This does not include relay operations which apparently were faulty because of inadequate equipment or improper connections.)

Column 6. Incorrect Relay Operations Due to External Causes. All cases of switch operation which investigation showed to be the result of faults or improper connections in auxiliary apparatus external to the relays themselves, or to power factor or other conditions on the system.

Column 7. Questionable Relay Operations. All switch operations which it has been found impossible to classify under columns 2, 5 or 6. In most cases the operation has been unsatisfactory, but owing to lack of evidence it was considered unfair to classify it as incorrect, particularly as a test made after the trouble

TABLE I—Analysis of Relay Operations on the 220 KV., 110 KV., and 60 KV., Transmission Network of the Pacific Gas and Electric Company

	1	2		3		4		5		6		7	
Year	Total Operations Involving Relays	Correct Relay Operations		*Relay Failures Due to Relay		*Relay Failures Due to External Causes		Incorrect Relay Operations Due to Relay		Incorrect Relay Operations Due to External Causes		Questionable Relay Operations	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1923	1,593	1,490	93.6	24	1.5	*	*	11	0.7	40	2.5	28	1.7
1924	1,884	1,699	90.2	31	1.6	*	*	3	0.2	108	5.7	43	2.3
1925	1,865	1,696	90.9	0	0.0	7	0.4	7	0.4	104	5.6	51	2.7
1926	1,939	1,728	89.2	1	0.0	16	0.8	11	0.6	147	7.6	36	1.8
1927	1,573	1,389	88.3	2	0.1	18	1.1	7	0.5	124	7.9	33	2.1

*See explanation of analysis, Cols. 3 and 4.
Percentages refer to total in Col. 1.

showed the relays to be operating correctly so far as could be determined.

Obviously every case of trouble on a network such as the one here under discussion involves a number of relay installations successively distant from the fault, and the proper selection as to the load or time whereby the more remote installations correctly function is not included in this tabulation.

The slight decrease in percentage of correct operations in the later years is attributed primarily to the increased accuracy and thoroughness with which the investigations have been conducted. The considerable reduction in the total number of operations involving relays in 1927 as compared with the previous year is a reflection of a reduction of the number of cases of trouble on the system, affected by the improved condition of the lines and the less severe climatic conditions prevailing. The number of cases of trouble causing material interruptions was approximately 558 in 1927 as compared with 689 in 1926.

It is of interest to analyze the data for 1927 as to the cause of the difficulties encountered. The two failures charged to relays (column 3) were due to dirty or pitted contacts. Eighteen failures due to external causes (column 4) were divided as follows:

Eight to mechanical trouble in switch gear.
Seven to failure of connections or auxiliary apparatus in d.c. tripping circuit.
Two to an accidental change in relay time setting while inspecting the relays.
One to incorrect balance between the settings of relays at different points.

Of the incorrect operations the seven cases charged to the relays (column 5) are divided as follows:

One due to sticking of the auxiliary contactor.
One to bent contact spring.
Five to broken tension springs.

The 124 cases of incorrect operation charged to external causes (column 6) were without exception attributed to the effect of power factor on directional over-current relays. This item comprises always the largest single class of incorrect operations of the protective equipment. It is of interest to note that there were during the year 638 operations of the switches involved in these failures, the total incorrect operations comprising 19½ per cent thereof and the number of operations causing interruption to service comprising 9.2 per cent of the total.

Oil Circuit Breaker Developments*

The efforts of the oil circuit breaker subcommittee have been directed under a plan whereby the program has been divided under manufacture, application and operation of oil circuit breakers giving all interested parties the fullest opportunity to participate.

The subject of oil circuit breakers is one on which there always should be the closest co-operation between operating men and manufacturers as it is only by such co-operation that the proper answer to the problems confronting each can be obtained. In the past year at least two operating men from member companies have joined the ranks of the oil circuit breaker manufacturing companies and this is one step in the many that are being taken to embody the ideas of operating companies into oil circuit breaker design and manufacture.

As to the trend of design and manufacture one manufacturing company submits the following:

The attention paid in recent years to interrupting capacities of circuit breakers is not diminishing and operating companies are setting still higher limits for interrupting ratings. This is indicated by the fact that circuit-breaker units for the interruption of 2,500,000 arc kva. have been built during 1927. Such units have been built both for 15-kv. service and for 220-kv. service, the latter on the system of the Southern California Edison Company. The first requirement of a circuit breaker is that it will open the circuit successfully when called upon to do so in event of a short-circuit or other fault condition. The requirements of correct system operation, however, demand a breaker that not only will clear the fault successfully, but also clear it in a minimum interval of time. Therefore the question of time is of importance second only to that of interrupting ability.

One device used to increase the rupturing capacity of high-voltage circuit breakers is a system of high-speed contacts. Certain small-scale investigations at relatively low voltage, principally by European engineers, have indicated that increase of speed above 5 ft. per sec. will be injurious to the breaker. Such a statement fails to take account of the radically different conditions existing on high-voltage from those that exist on low voltages. If a breaker will open its circuit in one cycle or less then an increase in speed will not be of any particular advantage and may even be a disadvantage. But if the breaker takes several cycles to open its circuit, an increase in speed will directly decrease the number of cycles of arcing and the increase in speed is advantageous. Many tests at different voltages and on different power systems indicate that the number of cycles of arcing is in inverse proportion to the speed for high voltages. Investigation of the possibilities of the use of multiple breaks has been made and there now are several breakers in heavy power service at 132 kv. utilizing this multiple break idea. It has been rather definitely established that the kw. sec. of energy released in the multiple-break breaker exceeds that in a properly designed two-break breaker for a given amount of power interrupted. Also, the complication of the mechanical construction of mutiple-break breakers seems at present to overbalance the advantages to be gained.

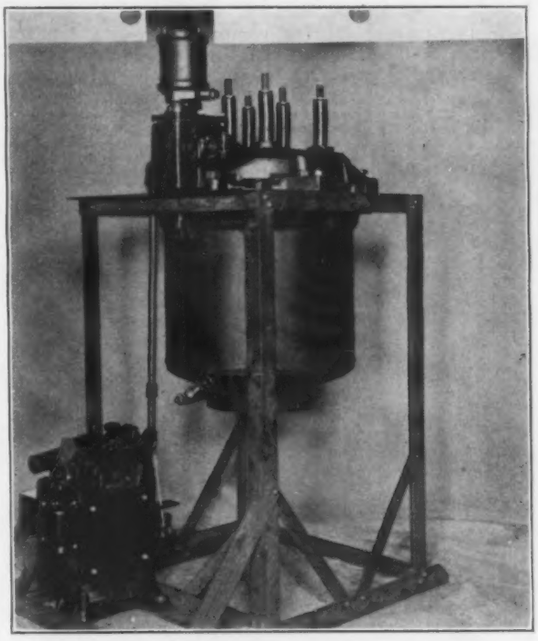

Fig. 1. Three-inch operating mechanism full automatic in all positions.

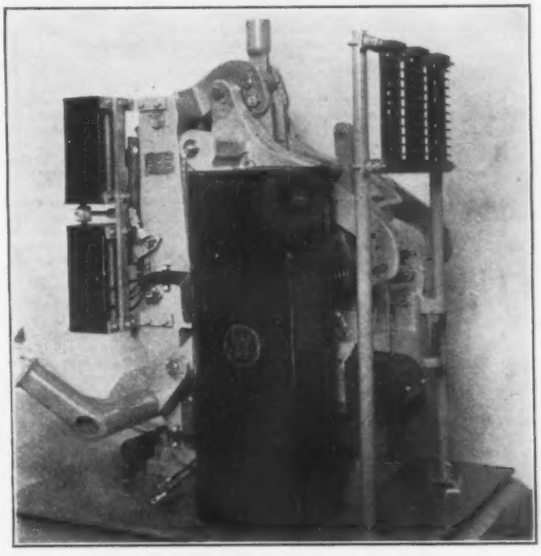

Fig. 2. Six-inch operating mechanism full automatic in all positions.

There has been brought out in the past year a new line of operating mechanisms which are trip-free in all positions of the closing stroke and at the same time have no traveling latches. Figures 1 and 2 show the 2-in. and 6-in. mechanisms respectively. A 4-in. mechanism also is made for the operation of medium-

* Report of subcommittee of electrical apparatus committee—C. E. Schnell, chairman. J. C. Albert, L. A. Buese, A. W. Copley, B. D. Dexter, F. D. Emory, A. Fulton, David Hall, J. N. Keith, D J. Kennelly, W. E. Melarkey, R. B. Pollock, S. P. Russell, E. K. Sadler, E. F. Sixtus, T. W. Snell.

capacity breakers. Motor operating mechanisms also have been developed, and one is shown in Fig. 3.

Investigations of means of opening circuits other than by the use of oil circuit breakers have been continuous for many years. The oil circuit breaker, however, up to the present remains the universal commercial switching device and the accumulated experience is such that the hazard involved in manufacturing and applying an entirely new type of device is considered to be great. This, however, will not prevent the continuation of the search for a more satisfactory type of device than the oil circuit breaker.

Another manufacturing company presents the following:

Since their earliest conception oil circuit breakers have been continually undergoing a process of development to keep step with the rapid advance in operating voltages and power concentration, and this has never been more a fact than during the last few years. At the present time this company is actively perfecting the designs of two types of high-interrupting-duty, round-tank, top-connected breakers for use in certain locations.

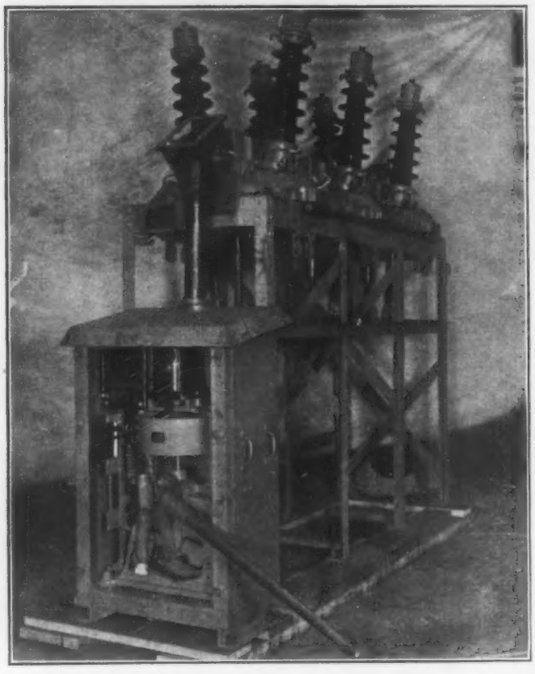

Fig. 3. Motor operating mechanism full automatic in all positions.

The first of these lines consists of breakers having three single-pole elements in separate round tanks with internal diameter of from 16 in. to 32 in. The interrupting duty range of these is from 400,000 kva. to 1,500,000 kva. and the voltage ratings from 15 to 37 kv. (See Fig. 4.) The second line of breakers, developed to provide a three-pole unit of comparatively high rupturing capacity and small overall dimensions, is shown in Fig. 5.

This breaker is a multi-pole, single round-tank, top-connected unit, and is being designed in capacities from 4.5 to 15 kv., 400 to 2,000 amp. and with interrupting ratings from 90,000 to 250,000 kva. Each of these breakers is adaptable to framework, cell or truck mounting and may be solenoid or motor operated, having balanced internal mechanisms, oil and gas-tight tanks and fitted with oil separating chambers.

In the large outdoor breakers many minor changes and modifications have been and are still being made to make the line entirely conform to the current, voltage and interrupting duty ratings as established by the N.E.M.A., N.E.L.A. and A.I.E.E. Certain modifications have been made in the construction of the explosion-chamber pots affording a more uniform internal pressure under varying arc currents. Heavy cast steel covers are being replaced by fabricated covers having equal or greater strength at a great reduction in weight.

The direct-acting overcurrent relays formerly furnished in the operating mechanism of certain breakers have been abandoned entirely. Manually operated breakers now are being furnished with H.F. type of operating lever attachments and overcurrent relays and trips are furnished as part of this attachment. Resultant tripping operation is much more dependable and embodies the trip-free feature. The new lines of breakers are adaptable to manual, solenoid or motor operation up to and including 88 kv. above which motor operated mechanisms only are recommended. Motor operated and manual operated mechanisms are inherently trip-free on overcurrent.

All new designs of large capacity indoor and outdoor breakers are being made to include the internal "balanced-pressure" operating mechanisms which tend to reduce the energy loss both on closing and opening and to reduce the necessity of counteracting springs and dash-pots. On motor-operated high-voltage breakers it has been found that one size of centrifugal motor mechanism will serve the entire line. This materially reduces the number of modifications in design which formerly were necessitated.

Some interesting developments have been made in the direction of iron-clad switch gear both for indoor and outdoor installation. The Wheaton 33-kv. switching station of the Public Service Company of Northern Illinois has a new installation of oil filled iron-clad switchgear having an interrupting rating of 1,000,000 kva.

Laboratory tests are being made on a comprehensive scale on various kinds of current-interrupting devices and mediums. Among the most recent tests being made are those on vacuum tube breakers and on forced-oil-jet breakers. Tests also have been made on all conceivable kinds of insulating and arc-quenching agents, both gaseous and liquid. Some of these have shown slightly better arc-damping qualities than oil as now used, but other factors such as corrosive and poisonous results, have prohibited their use.

A third manufacturing company reports as follows:

The design of a 6-break oil circuit breaker as developed in 1923 has not been changed fundamentally since that time, but marked improvement has been made by the facing and gasketing of all tank bushings and tank-top joints and the entire closing of all possible apertures through which oil might escape during operation.

The bushing-type current transformer housings have been extended to include and cover the terminal blocks and leads to the conduits outside the breaker thus completely protecting and supporting the transformers, terminal blocks and circuits. Oil dash-pots have been developed for smoothly cushioning the high-speed rotating members of circuit breakers of high rupturing capacity operating at 110 kv. and over. Pneumatic dash-pots in the control mechanism effectively cushion the moving parts in circuit breakers of lower rupturing capacity.

Many engineers have specified the introduction of manholes in the sides of tanks for inspection and overhauling and installation of such manholes has been made successfully without leakage or other ill effects and affording great conveniences to the operating engineers. The value of being able to operate large circuit breakers with small 24 or 48-volt battery installations has been recognized by many engineers and a large number of circuit breakers up to 132 kv. have been so equipped.

The use of motor-wound, spring actuated control mechanisms in conjunction with timing relays of standard make has been applied widely for the control of circuits where automatic reclosing circuit breakers are required. This arrangement has been installed for the operation of circuit breakers up to and including 73 kv.

The principle of the 6-break breaker is capable of expansion to ten breaks and such breakers now are available. These retain the fundamentally valuable feature that a multiplicity of breaks does not involve any greater possibility of insulation failure to ground by the addition of any porcelain posts or other supports. The whole switching equipment is supported by heavy, specially designed entrance bushings and a substantial single rotating insulator. (See Figs. 8 and 9.)

A fourth manufacturing company reports as follows:

Of the many developments made during the past year to oil circuit breakers of the pantograph type, two of the most outstanding are described herein. One of these improvements was

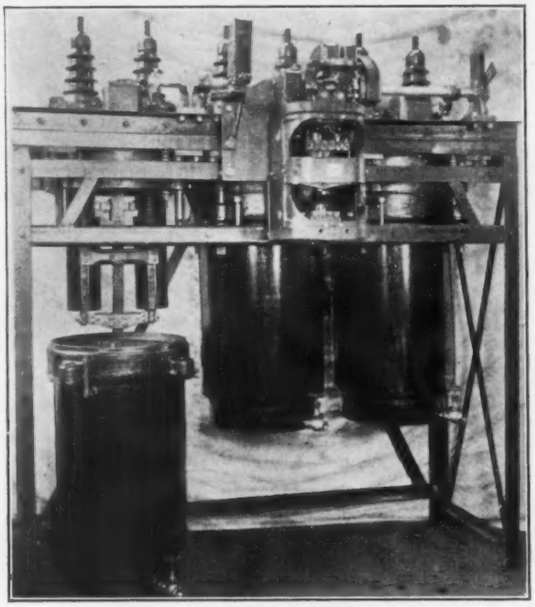

Fig. 4. Heavy-duty breaker for 25-kv. 600-amp. service.

the substituting of a butt-type arcing contact for the older type "wiping" contacts. The other improvement was the installing of a dash-pot in the pantograph assembly to give a quick, smooth check at the end of the opening stroke and thus do away with the need of an adjustable dash-pot connected to the operating mechanism as formerly used. While the accompanying illustrations show a 70-kv. breaker, all other breakers of the pantograph type are being similarly equipped.

The butt arcing contact shown in Figs. 10 and 11 consists of a red brass block milled to a snug fit so as to fasten securely to the tip of the switch blade and a swinging bracket which straddles the main stationary contacts. The face of the block on the

switch blade is milled to give a line contact with a copper bar fastened to the swinging bracket. The copper bar on the bracket and the brass block on the blade are easily renewed. Two flat steel springs are fastened to the bracket to give a pressure in excess of 35 lb. against the block on the blade and hence help to get the blade up to high speed in opening. The bracket is provided with a cross-bar at the top which stops the bracket travel by striking the main contact block.

Besides the two flat steel springs there are provided several bronze spring strips to give the necessary conductivity between the bracket and the contact block. The copper bar fastened to the bottom of the bracket follows the block on the blade, upon opening of the switch, until the blade is well out of the main contact clips. The parting of the two parts of the arcing contact is instantaneous and hence the ideal condition to prevent severe burning and "freezing." The velocity of each blade at the point where the arcing contacts open is 8 ft. per sec. and this speed increases to a maximum of 14.83 ft. per sec. at a point 4 in.

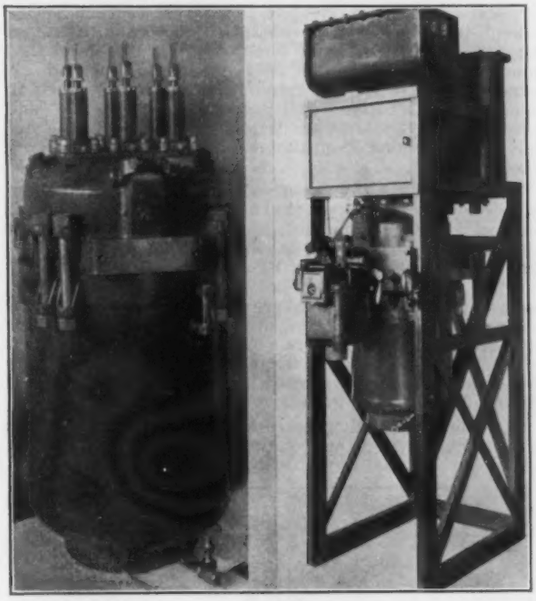

Fig. 5. (Left) Single tank unit type breaker for 15-kv. 600-amp. service.

Fig. 6. (Right) Metal-clad switching equipment for 15-kv. 600-amp. service. Breaker raised and padlocked in position. For indoor service, moderate interrupting capacity.

beyond the place where the arcing contacts part. As this is a 6-break switch, a gap thus is introduced into the circuit at the rate of 48 ft. per sec. at the instant the arcing contacts open and at a break of 24 in. the gap is being introduced at a rate of 89 ft. per sec. More than 100 oil circuit breakers of the larger sizes have been put into service with this type of arcing contacts and the results to date have been satisfactory. There has been no replacements of the butt contact blocks although the switches so equipped have interrupted numerous heavy short-circuits. Some of these shorts have been handled by switches in the 1,500,000-kva. class.

Time-motion curves of the opening stroke of many oil circuit breakers show severe cases of rebound at the end of the opening stroke. This was especially true where the dash-pot used on the older type breakers was not correctly adjusted. The older type dash-pot also retarded the speed of the switch to some extent both on opening and on closing. In order to obtain the high speeds at which these switches now operate it was necessary to design some means of checking the travel of the switch blades at the end of the opening stroke within as short a distance as possible thus taking advantage of the high velocity over a greater length of stroke and also preventing any jar at the end of the stroke.

Without changing the general design of the blade and contact assembly, dash-pots were installed in place of the plunger and plunger tube of each pantograph as shown in Fig. 11. The plunger rod was replaced by a plunger piston and the end of the plunger tube was capped. The cap has a ground clearance hole for the piston rod. The tube barrel is open at the bottom so as not to retard the closing stroke. The tube also is bored "oversize" to within about 1 in. of its upper end. This last inch of the tube barrel is a ground fit to the plunger piston. Large holes are bored in the tube up to about the last inch of length at the upper end where the holes are reduced in size until one very small hole is drilled about ¼-in. below the highest point of the plunger travel. For this last ¼-in. of plunger travel there is no outlet for the oil in the dash-pot except what can get through the space between the plunger rod and the ground hole in the plunger tube cap. This construction gives a smooth check to the switch blades over the last inch or less of the opening stroke, and has removed all rebound at the end of the stroke besides allowing higher velocity of blades over a greater portion of their travel.

The question was asked as to what would happen if a considerable amount of carbon were present in the switch oil. To answer this question, the dash-pots were tested in a 5-gallon can of oil into which had been poured 1-lb. of lamp black. It was found that the dash-pots still would function without any tendency to stick. The pantograph spring had plenty of pressure to force the carbon-and-oil mixture through the holes in the dash-pot tube and grind out any carbon that might catch between the plunger and cylinder.

Figure 12 shows some opening and closing time curves, the "inches from open and closed position" being the total for all six breaks. It may be noted that the time required for the blades to move from full-closed to full-open position is only 0.156 sec. and the time for the blades to move from open to closed position is 0.344 sec. This is high speed for an oil circuit breaker of such size.

A fifth manufacturing company submits the following:

Substantial progress has been made in the satisfactory operation of the higher voltage oil circuit breakers through improvements in the operating mechanisms and refinement in the manufacturing details. Field experience has demonstrated thoroughly

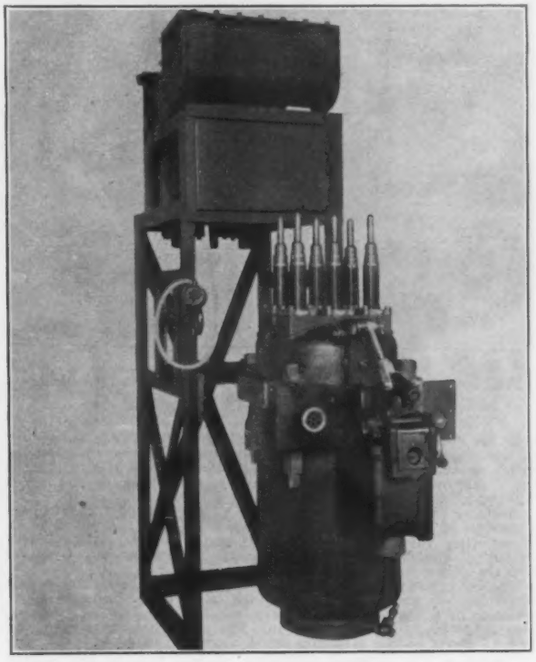

Fig. 7. Metal-clad switching equipment same as Fig. 6.

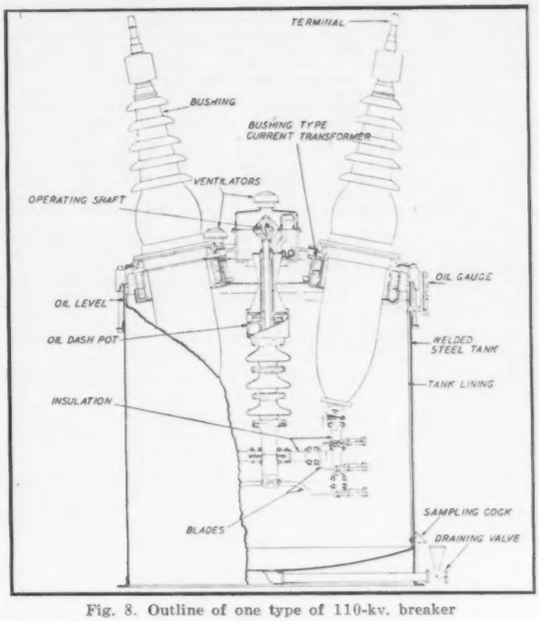

Fig. 8. Outline of one type of 110-kv. breaker

the value of multiple break and proper speed of operation. "Parkerizing" and cadmium-plating of metal parts to prevent deterioration, the use of higher tensile-strength steel in the operating linkages thereby reducing the inertia and improving the acceler-

ation of the breaker at the commencement of opening, all have tended to improve interrupting characteristics.

Constant study of bearings, shafts and pins both of the lubricating and non-lubricating types has resulted in special attention to workmanship and inspection during manufacture resulting in more reliable and smooth-working mechanisms. Latches have been given special treatment to render them durable and reliable and all parts subject to weather conditions have been made non-corrosive where possible.

The multiple break, so far as this company is concerned, has been standardized using four breaks up to 60 kv. six breaks on 73 and 110 kv. and ten breaks for 132 to 220 kv. applications. Numerous installations have demonstrated the value of the multi-break arrangements with proper opening speed characteristics.

During the past year 37, 50 and 110-kv. outdoor breakers have been tested by several utility companies to the limit the utility system could develop. This was approximately 90 per cent of breaker ratings. In some cases the duty cycle was more severe

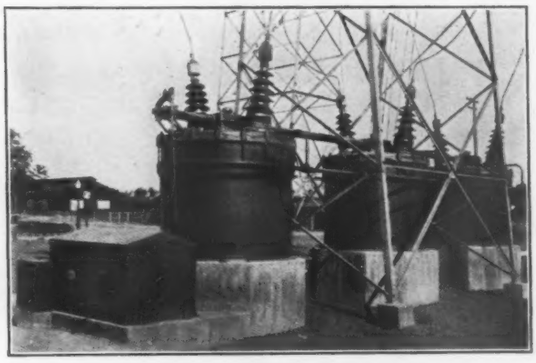

Fig. 9. 110-kv. breaker equipped with motor-wound spring-actuated mechanism.

than the standard duty cycle as it is known. A slight amount of oil was thrown in some of these tests. Satisfactory operation of an oil circuit breaker from the operator's standpoint should prevent all oil throwing and to secure this ideal situation special effort is being made.

A device for stopping the throwing of oil has been installed on a number of breakers ranging from 750,000 to 1,000,000 kva. in interrupting capacity. It has been tested at the factory with pressures simulating operating pressures and these tests indicate that the device is very effective.

One customer made tests with blasting powder in a 37-kv. unit containing oil and the muffler (which is of the centrifugal type) operated in a perfectly satisfactory manner at pressures ranging from 1,500 to 2,000 lb. per sq. in. It was gratifying to note also that all parts of the structure stood up in this test, as field tests indicate that the pressures generated by arcs are far below these pressures.

New designs have appeared more as additions to the present line of high-voltage breakers and these have included improvements that the broader study of the mechanisms, oil throwing, and weather proofing processes made advisable. This company has produced new 7.5-kv. outdoor breakers with an interrupting capacity of 50,000-kva., a single-pole, 2-pole and 3-pole design suitable for pole-top and structural steel framework mounting for small isolated outdoor stations. Motor mechanisms for operating indoor and outdoor breakers have been developed utilizing the principle of storing energy in a spring, and allowing the spring to close the breaker. These designs give positive quick closing and opening with full trip-free features, allowing the breaker to drop out entirely free of any inertia due to parts in the motor mechanism itself. A constant-potential motor which may be operated from a 200-watt potential transformer has been used. Every effort has been made to make this apparatus positive and reliable with a view to using it with any one of a number of standard reclosing, timing and lockout relays for use in unattended automatic substations.

It is the opinion that engineers in the past have been too conservative in their estimate of system growth and have not made sufficient allowance for deterioration in oil circuit breaker operating mechanisms, or have not given oil circuit breakers the proper amount of servicing in consideration of the conditions under which they may be operating.

Under the topic of equipment being developed tending to replace or supplement oil circuit breakers, this subcommittee is interested in a development reported as follows:

The fuse-break, load-interrupting switch consists of an air-break switch in combination with a group of tetrachloride fuses whereby the switch when closed carries the load current through its contacts in series with a fuse and upon opening the circuit one fuse of a group of three (and of smaller rating than the main fuse) is interposed in the circuit. This has the effect of increasing the load-breaking capacity of the air-break switch by putting the duty upon the fuse. This equipment is illustrated in Fig. 13 which shows a single-pole assembly. However, this equipment is made in 3-phase assembly with the arm for shifting from one fuse to another interlocked with the main operating mechanism. This switch has been developed for automatic operation by applying suitable tripping devices and now is being developed for automatic reclosing.

Application and Operation

Under this heading certain of the various member operating companies have submitted reports which have been briefed as follows:

Los Angeles Gas and Electric Company—No unusual circuit breaker installations have been put on the system during the last year. Some oil-insulated reactors have been installed to be used for current balancing purposes at the present time, but having 3 per cent additional reactance which will be used for current-limiting purposes in the near future.

A definite scheme of using bus tie and feeder reactors on 2.4-kv. and 4-kv. lines is being followed where the short-circuit currents exceed the limits of either the regulator or a moderate-duty breaker. The question of keeping synchronous apparatus on the lines, service and mechanical stresses also govern this use of reactors.

Automatic reclosing of breakers is not used, but supervisory control is used in several stations. One recent installation in a substation has an ultimate of 60 control or supervisory positions. It is believed that more reliable service can be given by this method. A very few a.c. motor-operated mechanisms are used in consumer substations and a.c. through overload and transfer relays is used for tripping in these substations, but in all stations of any importance d.c. is used closing and tripping.

There are so many factors entering into the question of "over-sized" breakers that it is difficult to say where to stop. New developments in breakers, system growth in unexpected locations, etc., are frequent factors in circuit breaker obsolesence. Flexibility in station design, so that new designs of breakers may be installed when necessary and older breakers moved to points of less severe duty will help in securing the greatest possible life from circuit breakers. On a rapidly growing system, seven years for larger stations and five years for smaller stations seem to be the safe time limit for forecasting system growth.

A record of breaker performance under short-circuit conditions, giving the conditions of breaker and the

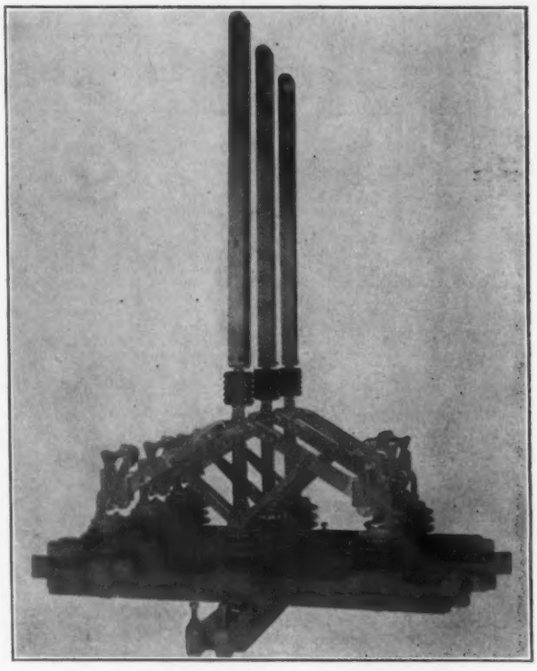

Fig. 10. Butt arcing contact used in one type of breaker.

probable amount of current interrupted together with a study of voltage and current charts and oscillograph records will be of great service in rating breakers.

Low-voltage high-current overall tests on circuit breakers and relays are made before putting them into operation. In special cases the normal operating system has been "shorted" to test relays and breakers. A "system calculating board" is used to check the duty on breakers. Each short circuit is checked by this method and the board used in figuring the probable duty required of new installations.

On existing breakers a reduction in the number of parts, elimination of misalignment of contacts due to bushing movement, and reduction in number and finesse of adjustments is recommended.

Southern Sierras Power Company—Of the reclosing type of breakers there are only twelve installed on this company's system at present, all of which are on 2.3-kv. distribution lines. Operation of the breakers so far has been very satisfactory. The present setting of the breakers is for two reclosures timed 5 to 8 sec. and a lockout on the third trip after a total elapsed time of 15 sec. This setting seems satisfactory although no experiments have been made with other settings.

This company has no definite policy for "over installing" circuit breakers (in size) to take care of future system growth, but usual practice is to install for a growth expected within a period of five or ten years. However, the rate of growth and other variables enter to affect the individual installations.

Bureau of Power & Light, Los Angeles, California—For the past year the effort of this utility has been to improve its 33-kv. distribution system against failure of oil circuit breakers.

TABLE I—Operating characteristics of 6-Break Circuit Breaker No. 7137—Before and After Making Changes.

	Before Making Changes	After Making Changes
Opening.		
Minimum volts at which switch would open	75.000	75.000
Amp. taken by opening coil at 110 V	35.000	14.000
Maximum velocity of break in ft. per sec	38.500	78.000
Velocity at arcing contacts in ft. per sec	25.000	46.500
Time for total travel of blades—in sec	0.145	0.105
Time for total travel of blades—in cycles	7.250	5.250
Time from energizing control circuit for arcing contacts to open—in sec	0.240	0.192
Time from energizing control circuit for arcing contacts to open—in cycles	12.000	9.600
Closing.		
Minimum volts at which switch would close	100.000	80.000
Amps. taken by closing coil at 110 V	137.000	105.000
Maximum velocity of closing in ft. per sec	18.000	34.500
Velocity at arcing contacts in ft. per sec	18.000	33.500
Time for total travel of blades—in sec	0.332	0.230
Time for total travel of blades—in cycles	16.600	11.500
Time for energizing control circuit for arcing contacts to close—in sec	0.630	0.408
Time for energizing control circuit for arcing contacts to close—in cycles	32.000	20.400
Total break in inches	24	35

From the system calculating table the kva. breaker capacity required on all transmission and distribution lines was determined. A survey of all existing oil circuit breakers then was made and from a study of past performances of the different types of breakers an attempt was made to give each type a kva. interruption rating. This survey showed that there were in use on the 33-kv. system many different styles of circuit breakers (mostly of one manufacture) differing principally in minor features. All of them could be divided broadly into three types which differed radically in their construction and performance.

Effort therefore was centered around these three principal types of breakers to improve each type in all the details shown to be desirable by experience and to conduct further experiments in conjunction with the manufacturer to determine what other improvements could be added. From experience it was determined that a rating of 250,000 kva. could be given to the weakest of these three types, when all known minor improvements were added to it. This is a 2-break switch with tank capable of standing 150 lb. pressure per sq. in. The second type could be relied upon to break 500,000 kva. and the third type was tentatively rated at 1,000,000 kva. Any circuit breaker whose tank was not strong enough to stand 150 lb. per sq. in. was given no rating whatever.

TABLE II—Operating characteristics of 6-Break Circuit Breaker No. 8157—Before and After Making Changes.

	Before Making Changes	After Making Changes
Opening.		
Minimum volts at which switch would open	90.000	70.000
Amp. taken by opening coil at 110 V	35.000	7.000
Maximum velocity of break in ft. per sec	36.000	81.000
Velocity at arcing contacts in ft. per sec	32.000	35.000
Time for total travel of blades—in sec	0.180	0.117
Time for total travel of blades—in cycles	9.000	5.850
Time from energizing control circuit for arcing contacts to open—in sec		0.160
Time from energizing control circuit for arcing contacts to open—in cycles		8.000
Closing.		
Minimum volts at which switch would close	100.000	85.000
Amp. taken by closing coil at 110 V	164.000	90.000
Maximum velocity of closing in ft. per sec		28.000
Velocity at arcing contacts in ft. per sec		27.500
Time for total travel of blades—in sec		0.192
Time for total travel of blades—in cycles		9.600
Time from energizing control circuit for arcing contacts to close—in sec	0.384	0.300
Time from energizing control circuit for arcing contacts to close—in cycles	19.200	15.000
Total break in inches	30	30

It was then decided to change all breakers to one of these three standard types either by replacement or by rebuilding. The type chosen to be used was determined by the use of the short-circuit calculating table. The

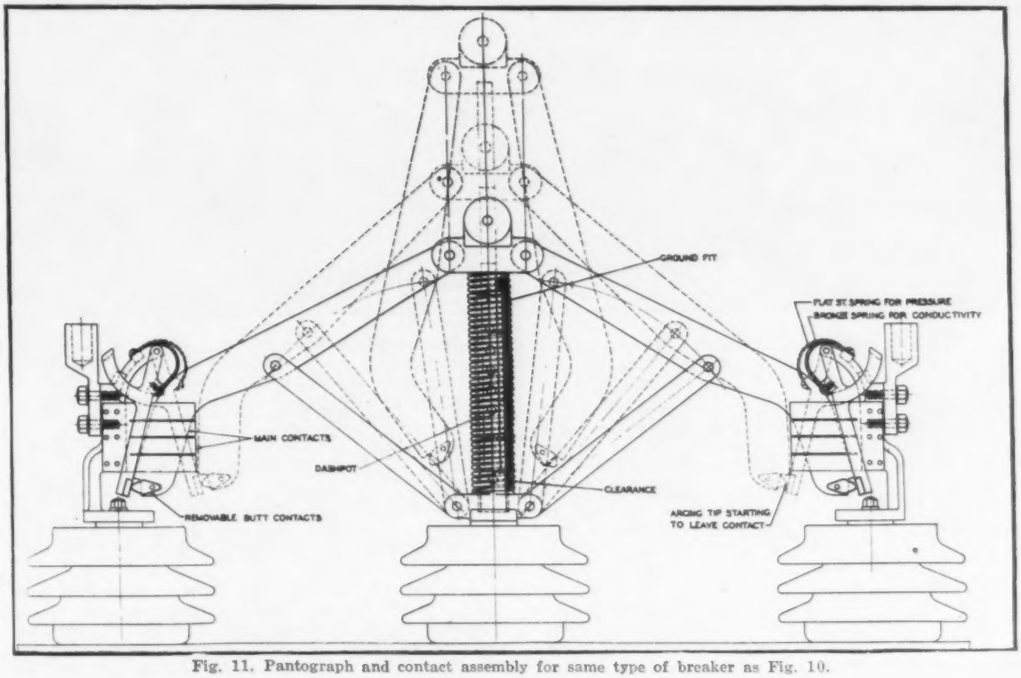

Fig. 11. Pantograph and contact assembly for same type of breaker as Fig. 10.

manufacturer entered into the experimental work endeavoring to improve still further these three types of breakers. The principal improvements consisted of strengthening the tanks, speeding up the opening and closing of the contacts, and decreasing the time and current required by the operating mechanisms.

As stated before all tanks were made to stand at least 150 lb. per sq. in. The type rated at 1,000,000 kva. was required to stand at least 1,000 lb. per sq. inch. Velocity of gap opening at the time the arcing tips opened was increased to between 35 and 45 ft. per sec.

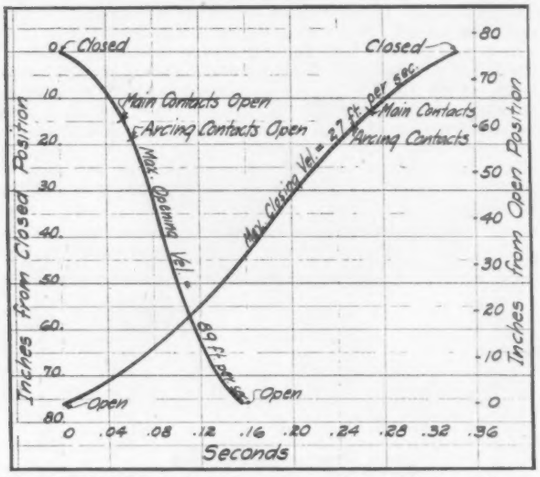
Closed
Closed
Main Contacts Open
Arcing Contacts Open
Max. Opening Vel. = 89 Ft. per sec.
Max. Closing Vel. = 27 Ft. per sec.
Main Contacts
Arcing Contacts
Open
Open
Inches from Closed Position
Inches from Open Position
Seconds
0 .04 .08 .12 .16 .20 .24 .28 .32 .36
0 10 20 30 40 50 60 70 80
80 70 60 50 40 30 20 10 0

Fig. 12. Mechanical time curves of a 6-break 70-kv. 400-amp. breaker of type similar to Figs. 10 and 11.

To show what can be accomplished in this manner there are included two tables showing the operating characteristics obtained from two types of breakers used. These tables show the characteristics before and after making changes decided upon, after the many experiments made up to the present time. So far there have been no circuit-breaker failures on the 33-kv. system at any of the stations where breakers have been installed or changed to conform to the limits of the ratings decided upon for these three types of breakers.

Due to the added improvements, especially to the additional speed of opening, it is believed that a conservative rating has been placed on these oil circuit breakers and that they are capable of even greater duty than imposed upon them at present. Future growth and experience will have to determine just how much.

San Joaquin Light and Power Corporation—Augumented power resources of this system required the gradual increase in size of oil circuit breakers to meet the duty imposed. For transmission voltages of 70 kv. and 120 kv. as well as distribution voltage of 11 kv. these needs have been met very well by oil circuit breakers of the multi-break type. Small breakers have been moved to locations where the duty is within their limits and indoor breakers have been replaced almost entirely by outdoor types.

No use has been made of back-up breakers or series feeder reactors for lessening the duty on oil circuit breakers, but the bus sectionalizing scheme has been used with success.

Installations of automatic reclosing breakers have been functioning satisfactorily with no undue failure of operation. The trend has been to reduce the number of reclosures before lockout from three to two and even to one in some cases. In certain localities where extremely deep wells with vertical pumps are common the plan is to reduce the number of reclosures before lockout to one with from three to five minutes elapsing before this one reclosure.

To determine the proper oversize of breakers to install in any particular station careful consideration is given of the probable increase in capacity due to future growth as well as to the economics of the investment as regards equipment available, initial cost and annual charges. It is safe to say that ten years is considered as an outside limit beyond which no plans can be made. The average is nearer five to seven years. It is extremely difficult to anticipate with any degree of certainty future requirements to prevent this rapid obsolescence of oil circuit breakers. This results in earlier replacement and rapidly depletes the depreciation reserve, but with everything considered this appears to be the best answer.

All oil circuit breakers together with their protective relays are given an overall acceptance test by the operating department before being placed in service. This is accomplished by passing current at low voltage through the breaker and in varying values to determine operating characteristics of the switch and the relays. This has been particularly valuable with oil circuit breakers having bushing-type current transformers for relay protection and in which the secondary leads are of considerable length.

Southern California Edison Company—The Southern California Edison Company recently has constructed a new 220/60-kv. transmission substation called Lighthipe. Attention is called to some of the features of this station because its shows the trend of Edison Company practice in the application of oil circuit breakers.

Calculations showed that with the proposed ultimate installation and with all the 60-kv. lines tied together on one bus the short-circuit duty would exceed 3,000,000 kva. For economic reasons the Edison Company has decided to limit the interrupting duty on its 60-kv. breakers to 1,500,000 kva. This was accomplished by splitting the 60-kv. buses into three sections and operating the two end-sections in parallel only through the 220/60-kv. transformer banks. Oil circuit breakers are provided for tying the bus sections together so that the center section, which represents a source of power from the Long Beach Steam Plant, may be connected to either end-section as desired. The breakers used were 6-break, 600 and 800 amp., solenoid-operated. They are similar to the older type 5D6 except that they are of heavier construction throughout and use a high head of oil over the contacts.

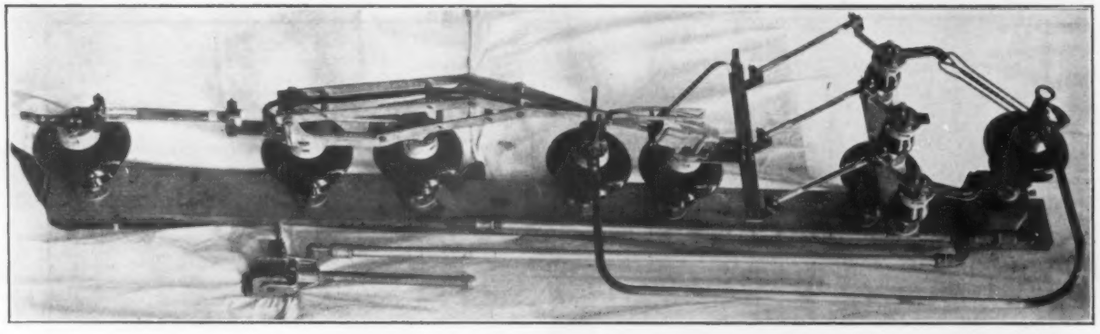

Fig. 13. A fused disconnecting switch.

The 220-kv. circuits are provided with 220-kv., 600-amp. oil circuit breakers having a rated interrupting capacity of 2,250,000 kva. The Edison Company has decided to limit the duty on its 220-kv. breakers to 2,250,000 kva. and expects to accomplish this by sec-

tionalizing the system. The first step, however, will be to replace the smaller breakers now installed.

Differential protection was applied to each section of the 60-kv. buses at Lighthipe. When the installation is completed there will be nearly 20 breakers on one section of the bus which must be tripped simultaneously. It was found necessary to have a low tripping current per breaker in order to avoid using a 250-volt battery or very large d.c. operating buses.

The 50,000 kva. synchronous condenser starting and running oil circuit breakers are of the outdoor type. The Edison Company previously has used indoor breakers for large machines as high-current outdoor breakers have not been available. The running breaker is rated at 25 kv., 3000 amp. and the starting breaker is rated 15 kv., 2000 amp. The station light and power service is taken from the running buses of each of the two condensers through 600-amp. breakers of the same type and without reactors. Bushing-type current transformers in these breakers are used for transformer and condenser differential protection.

The use of low-voltage taps on the transformer windings for starting the condenser results in a higher ratio of the bank during starting than that obtained while the condenser is running. This upsets the balance between the current transformers used on the high and low side of the bank for differential protection. This unbalance during starting was sufficient to cause the relays to trip and was prevented by using bushing-type current transformers of different ratios in the starting and running breakers with their secondaries paralleled. This is made possible by the fact that only one of the breakers is closed at a time and that the impedance of the current transformer in the open breaker is high enough to have very little effect on the current supplied by the current transformer in the closed breaker. A low relay setting therefore can be used and sensitive protection can be maintained during starting. It is believed that this method is more satisfactory and reliable than cutting out the transformer protection during starting by means of switches. A bushing-type current transformer in the station power breaker is included in the condenser transformer differential circuit in parallel with those on the running and starting breakers to prevent the condenser transformer from tripping on station power faults, thus allowing the station power breaker to clear the fault.

Since the pallet switches on oil circuit breakers often are used for interlocks in relay circuits it is important that pallet switches be made as reliable as possible. When starting condensers, in order to reduce the current required to pull the rotor into synchronism, it is necessary to close the running breaker as soon as possible after the starting breaker has opened. This was done by means of a pallet switch on the starting breaker which was timed to close as soon as the starting breaker contacts opened. The delay was not more than about 30 cycles. On most breakers no provision is made for timing pallet switches and usually it is quite difficult to change those existing or to add others. It would seem that such a feature could be incorporated in the design of pallet switches without sacrificing reliability.

All bushing current transformer leads should be brought down to terminal boards in some convenient location, preferably in the solenoid housing. This is of considerable advantage in making connections and testing the various ratios, as well as for inspecting connections. The use of bushing-type current transformers for bus-differential protection requires that all the current transformers in the breakers feeding that section of the bus be paralleled. This can be accomplished most easily by looping the secondaries from breaker to breaker and taking a parallel tap to the relay which may be located at some distant point. The accidental opening of any current transformer supplying current will cause the relay to trip. It is important, therefore, to place the current transformer terminal boards in the most convenient location for the leads as well as to furnish terminals to which a reliable connection can be made with large wire. If it is desired to have short-circuiting and disconnecting switches for testing the individual current transformers, space should be provided in the solenoid housing for them. It would seem that the manufacturer should give these details some consideration.

Most of the 220-kv. oil circuit breakers on the Edison system have trip-free closing mechanisms. This has been considered a desirable feature because when a breaker is closed to test a line which has been out of service there is danger of causing surges in the system and also injuring the breaker if it continues to "pump" in and out when there is a fault on the line. This pumping action can be avoided by a so-called trip-free mechanism, consisting of a resetting device on the closing relay which makes it necessary for the operator to return the control handle to a neutral position before the breaker will reclose after being tripped by the relays. Some of the manufacturers do not include this feature in their standard equipment.

The Edison Company is making a number of changes in its 60-kv. network which when completed will reduce greatly the interrupting duty on its oil circuit breakers. The small substations are to be fed from one of the major transmission stations only, by means of two feeders which for reliability are to be carried on separate poles as much as possible. Direct connections between the major stations with 60-kv. lines will be avoided. Whenever a small substation is connected with more than one major station, only one connection will be energized normally. By properly arranging the transformers and lines on the various sections of the bus at the major stations it will be possible to limit the short-circuit duty to 1,500,000 kva. at all points in the 60-kv. network. The need of larger breakers as the system grows thus will be avoided. This seems to be a logical solution to the oil circuit breaker problem. Efforts then can be directed toward improving present breakers rather than experimenting with larger and more cumbersome breakers.

Pacific Gas & Electric Company—The following is submitted as covering the most recent application of 100-kv. and 15-kv. oil circuit breakers on the system of this company.

At Newark and Martin substations Type FHKO-39 oil circuit breakers have been installed. This equipment is rated at 400 amp., 110 kv. and is controlled with MK-4 motor operators. All six bushings of each breaker are equipped with bushing-type current transformers, three current transformers being connected to ammeters and wattmeter on each circuit and the remaining three current transformers connected to the circuit relays. These breakers, like all other 110-kv. breakers on this system, are mounted with the poles on 12-ft. centers. At each breaker d.c. control sectionalizing switches are installed which permit the isolation of defective breaker control circuits.

In order that these breakers may be disconnected at any time without interruption to service, steel towers are erected over each breaker upon which are located bypass and disconnecting switches. These towers are 50 ft. in height and switches mounted thereon are remotely controlled mechanically from the ground level. Two control levers are employed, one to actuate the six disconnecting switch blades and the second to operate the three bypass switches. In Fig. 14 is shown an application of high voltage oil circuit breakers on 100-kv. circuits and a similar arrangement is used also on 60-kv. circuits.

At San Francisco an automatic railway substation known as Station N has just been completed, using steel throughout in the construction of the bus and oil circuit breaker compartments.

Type B26, 15-kv. oil circuit breakers are installed for the two incoming 11-kv. cables, station service transformers and two 1,500-kv. converters. These breakers are economical of space in that all three poles are contained in a single tank. Another point of interest connected with this breaker installation is the so-called "roll-out" feature without the expense of standard truck-type design.

The circuit breakers, solenoids and closing relays are mounted in a steel frame which is supported on wheels. A track is installed in each cell and the circuit breaker may be rolled out for inspection or adjustment. Instead of lowering the tank it is unbolted and the switch frame hoisted from the tank after being rolled from the cell. When in operation the switch truck is held firmly on its tracks and bolted to the floor.

Extra-flexible leads are used for connecting the six main terminals which may be unbolted in a minimum of time. The connections for the interlocking and control wires are made with standard train-line connectors and multiple conductor cable. A material saving in cell floor space and height due to the roll-out feature is effected and it is believed that there will be a saving in maintenance costs due to the accessibility, ease of handling and inspection.

Lightning Arresters*

A study of all of the reports submitted indicates that the companies of the state use lightning protection only in proportion to the severity of their particular lightning conditions. All forms of arresters that have been manufactured in the past ten years appear to be in use with no particular preference for any one type. Damage to arresters themselves appears to be relatively small. Interruptions due to lightning, in general, cause relatively small damage, the principal units affected being distribution transformers, insulators, and bushings.

The sub-committee on lightning arresters at the beginning of the year determined on a program for the year as follows:

From the operating companies, to determine (first) their practices regarding the installation of lightning arresters, (second) the extent of system troubles and apparatus damage from lightning, and (third) the extent of troubles due to lightning arresters themselves. From the manufacturing companies, to ascertain what new or improved apparatus might be available and what new and improved methods of testing lightning arresters were in use.

Reports were received by the committee from practically all the operating companies. These reports indicated in general that the companies in the northern part of the state were comparatively free from lightning troubles and therefore used comparatively few lightning arresters. The companies farther south apparently have more lightning troubles and use a correspondingly larger number of lightning arresters. The worst lightning conditions apparently are in the territory of The Southern Sierras Power Company in the southeastern part of the state. The reports of all companies seem to indicate that the damage from lightning is confined largely to distribution transformers, line insulators, disconnect insulators and switch bushings. Very few cases of damage to major apparatus other than bushings were indicated in the reports. In a great many cases, as indicated in the reports, the lines will relay out due to insulator flash-overs and may be immediately placed back into service.

The report of R. V. Hall of the San Joaquin Light & Power Corporation is particularly interesting and is quoted in part as follows:

> It has been the trend on the San Joaquin Light & Power Corporation's system for the last seven years to discontinue the use of lightning arresters on tranmission lines of 30, 60 and 110 kv. whenever damaged or obsolete. The general practice is to install arresters directly on the line, with one or two exceptions, in which cases they are connected to the main bus.
>
> The trend to discontinue arresters on transmission lines was a question of economics. The usual number of trip-outs due to lightning occurred in stations that were well protected as well as in unprotected stations. The damage usually was no greater in unprotected stations than in those where arresters were installed and on direct strokes it usually was confined to the structure, pole, tower or apparatus hit.
>
> Induced voltages from lightning on high voltage transmission lines seldom are greater than the surge voltage due to switching operations on account of the high frequency of the lightning which is damped out in a short distance. See A.I.E.E. Journal, May 1927, Page 459.
>
> Another element that was considered seriously before deciding to discard arresters on the transmission lines of this system was the fact that there were so few lightning storms during the year, usually from two to six, with one or two of these more or less localized in one corner of the system.
>
> It was decided as the future policy of the company to install arresters on distribution lines located at elevations of two and three thousand feet and above where lightning is more frequent.
>
> The present number of arresters in service at the time of this writing are shown in Table I.

Appended to Mr. Hall's report is a detailed tabulation of system troubles due to lightning for the years, 1925, -26 and -27, which may be summarized as follows:

> In 1925 there were 41 transmission troubles due to lightning or 13.6 per cent of the total number of transmission troubles. Of these 41 cases there were two cases of damage to station transformers, one case of a small station burning down and one case of a 110-kv. switch bushing break-down. The others were practically all line trip-outs due to insulator flash-overs. Only in the case of the station burning down was there any serious interruption to consumers.
>
> During 1926 there are listed 38 transmission troubles due to lightning or 14.5 per cent of the total transmission troubles. Of this number there were three cases of station transformer trouble recorded. In 1927 there are listed a total of 13 cases of transmission troubles due to lightning during the first eleven months of the year or 6.7 per cent of the total transmission troubles.

Mr. Hall's report is accompanied by a map of the San Joaquin Power Company's system shown in Fig. 1 and upon which all lightning troubles for the three years have been plotted. This map is particularly interesting in that it shows the lightning troubles largely concentrated in a few definite districts with only occasional hits on the rest of the system.

The Southern California Edison Company has made extensive studies of lightning troubles during the past few years. No detailed report of these troubles is available as yet, but a statement was made that approximately 20 per cent of all their troubles were due to lightning. This does not take into account the severity or extent of the troubles, but merely indicates that 20 per cent of the total troubles appear to be due to lightning. It also was brought out in the discussions that certain well defined districts on the Edison Company's system were particularly subject to lightning disturbances. For example, the Antelope Valley is subject to very severe lightning conditions at certain seasons of the year.

On the Los Angeles Bureau of Power and Light system very careful studies have been made of interruptions due to lightning for the past ten years. These studies indicate that the great majority of all lightning troubles are confined to insulator and switch bushing flash-overs. There is no case of serious damage to any major apparatus. The Bureau uses lightning arresters only at the more important stations, such as the generating stations, receiving stations and at one or two other places where experience has shown them to be

TABLE I—Arresters in Service on the San Joaquin Light and Power Corporation System.

Number	Type	Voltage (kv.)
1	Oxide film indoor	110
15	Electrolytic	70
1	Electrolytic	30
3	Electrolytic	11
9	Oxide film	11
1	Graded gap	11

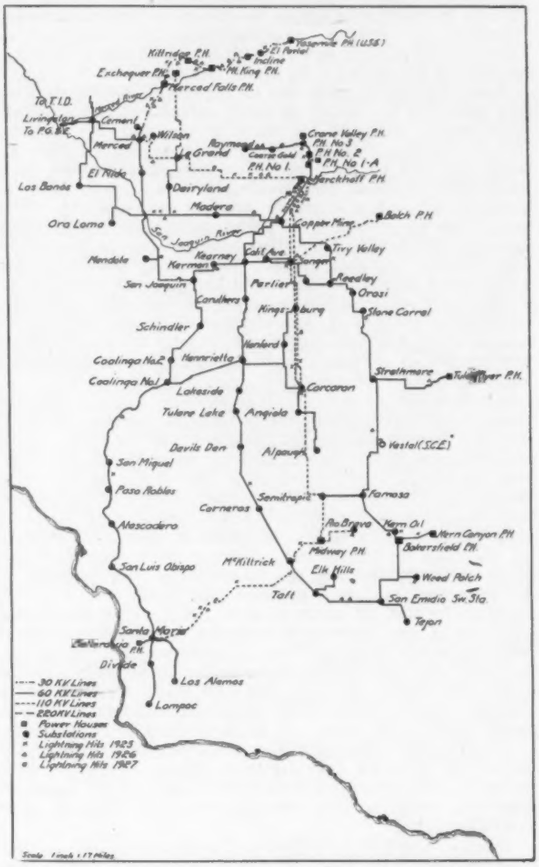

Fig 1. Map of San Joaquin Light & Power Corporation's major transmission system showing location of lightning disturbances.

* Report of subcommittee of electrical apparatus committee—H. H. Cox, chairman. K. B. Ayres, C. F. Benham, L. A. Buese, R. E. Cunningham, B. D. Dexter, H. E. Fuqua, R. V. Hall, J. C. Jones, J. N. Keith, W. C. Smith, E. R. Stauffacher.

desirable. The areas most subject to lightning on the Bureau's system are Hollywood and the San Fernando Valley.

K. B. Ayres of the San Diego Consolidated Gas & Electric Company submits a report for his company which is quoted in part as follows:

Within certain limits the company uses lightning arresters systematically and beyond those limits they are installed only here and there, the location being based on judgment rather than on any information accumulated from past experience with lightning. Experience with lightning has been very slight in this territory.

Prior to five years ago a great many graded-shunt-resistance multi-gap arresters were used located principally on the step-down stations of large capacity on the 11-kv. system. Since that time, however, due to the number of fires that they caused on structures, they have been abandoned and this type discarded entirely. Arresters of the compression-chamber or auto-valve type are used now. These arresters are all installed on lines, there being arresters located at each station, on poles or in the station itself according to the system they protect and the method by which the wires enter the station.

Arresters are not now being installed on each large step-down banks as formerly was done. It is deemed unnecessary. Arresters are used at the stations on all feeders, tie-lines and transmission lines of 2.3 kv. or beyond. There are on the 66-kv. and 88-kv. system four arresters, two of which are electrolytic and two of which are auto-valve. There are on the 11-kv. system probably a total of 40 sets, on the 4-kv. systems, probably 20 sets, and on the 2.3-kv. systems about 15 sets.

As to the extent of interference with operations due to lightning, it has occurred so very seldom that there are only a very few interruptions to service which could be traced with any degree of certainty directly to lightning for several years past.

On a few occasions small distribution transformers have blown up and this, of course, can be traced directly to a stroke of lightning—two cases in the last four years. It so happens that each time a storm of any severity has occurred a number of primary fuses have been blown; there are no means of determining whether these are blown due to the effects of lightning or whether the trouble has been caused by secondary wires blowing together and shorting. In the majority of cases in which bushings have flashed over it has been attributed to the formation of dust which adhered to the bushings due to the siphoning of oil, and caused them to flash over when they became wet. The interruptions to service to important customers or large groups of customers directly traceable to lightning are practically limited to the two cases as stated before, and they did not extent over a very great area nor a considerable period of time.

In recent years there has been only one case of system trouble caused by the failure of the arresters themselves. This was on a 4-kv. line, the arresters being installed on a pole one span beyond the cable terminal leading from the station to the line. It has been impossible to determine what caused the failure, but in this case three auto-valve arresters were installed on a 4-kv. feeder and two of them blew up, burning down the line wires which were of 4/0.

The reports of the Los Angeles Gas & Electric Corporation and of The Southern Sierras Power Company indicate probably the most general use of lightning arresters of any of the companies of the state. The Los Angeles Gas & Electric Corporation's standard practise is to protect all lines with lightning arresters. While they have not kept a separate record of lightning disturbances, their report indicates that their lightning protection has been relatively effective. They had no serious damage in any of their stations due to lightning. They report five cases of failure of the arresters

TABLE II—Arresters in Service on The Southern Sierras Power Company System.

Number	Voltage (kv.)	Type
1	115	Auto valve
2	115	Oxide film
5	88	Electrolytic
2	88	Oxide film
4	88	Resistance type
6	55	Electrolytic
2	55	Oxide film
4	55	Resistance type
6	33	Electrolytic
10	33	Auto valve
3	33	Oxide film
37	33	Graded shunt resistance
1	15	Auto valve
4	15	Oxide film

themselves, all of the graded-resistance type. Three of these failures were caused by lightning hitting the lines very close to the stations in which the arresters were installed and in the other two cases the causes were not determined. These arresters all were protected by fuses and in every case the lines were immediately restored to service.

The report of The Southern Sierras Power Company as submitted by J. M. Keith is as follows:

Lightning arresters on The Southern Sierras Power Company system as of five years ago were rather few and were installed only in districts most affected by lightning. They usually were connected to the station bus and were of the electrolytic or resistance type.

Present policy is to install them on all important lines at all voltages. The arrester is connected to the line ahead of all station equipment. Two districts on the system, the Nevada district and the Imperial Valley district, are more affected by lightning than any of the other districts, hence more arresters are used in these two regions than in the others. All new arresters for the higher voltage lines (115-kv., 88-kv. and 55-kv.) are of the oxide-film or auto-valve type, there being considerable question to us which is the best. On 33-kv. and 15-kv. lines the oxide-film or auto-valve type arresters are installed at the main substations and a graded-shunt-resistance type is used at the outlying substations.

In Table II is given an approximate list of arresters on the company's system as regards type and voltage:

Interference with operation has been very slight on lines which are fully protected by lightning arresters. There have been several cases of insulator failure, but no damage to major apparatus has occurred. Usually during lightning trouble the automatic oil switches relay open and the lines clears themselves and service can be restored immediately.

On unprotected circuits there have been several cases of damage to apparatus, mainly transformers. During the past year-and-a-half a bushing was lost on a large power transformer and several 33-kv. distribution transformers were burned out due to lightning.

There have been no cases of arresters of the auto-valve or oxide-film type failing. There has been one case of bushing failure on an 88-kv. electrolytic arrester. With the graded-shunt-resistance type of arrester there have been two or three cases where the resistances have burned out and required replacing, but no other damage to apparatus resulted.

Representatives of the manufacturing companies submitted reports covering the apparatus available from their particular company. No new apparatus for lightning protection appears to be available, but both of the larger companies are now doing very extensive work in the testing of their arresters, and are making improvements in their arresters as a result of this testing work. Both companies are using the cathode ray oscillograph and lightning generators in their testing work. It is possible now to test an arrester with a discharge from a lightning generator having a potential of as high as 4,000,000 volts and to measure the voltages and currents of this discharge by means of the oscillograph. These discharges occur in such short periods of time as a few micro-seconds, and yet with the apparatus available it is possible to take these oscillograms with the record of the discharge at approximately the center of the oscillograph film. This is accomplished by means of switching devices which first set the oscillograph equipment in operation and then produce the lightning-generator discharge. This, of course, is only a laboratory method and as such cannot be used to record actual lightning discharges in the field.

At the San Francisco meeting it was the privilege of the committee to hear an address given by Dr. Harold Norinder, engineer of the Royal Board of Waterfalls of Sweden, in which he described lightning studies being made in his country under his supervision. The most interesting point of his lecture had to do with the development of a cathode ray oscillograph which could be used for field tests of actual lightning conditions, a thing that has not been possible heretofore.

The Dispatching Organization and Its Place in the Scheme of Things

By H. W. Neir*

The Western electric utility in virtually every instance has evolved into a system having interconnected generating plants and sources of power at widely separated points as regards load centers. Networks of transmission lines, substations and distribution lines comprise channels for delivery of the manufactured product to the premises of the consumer. Certain facilities also are provided to insure that the quality of this product shall be maintained at a uniform standard regardless of the quantity demand. With development of the system from a simple, single-plant affair to one of modern complexity arose the necessity of providing an agency to co-ordinate the various units involved in processes of generation, transmission and distribution to the end that the business proceed in an orderly manner, furnishing uninterrupted satisfactory service on an economical basis. This brought into being the dispatching organization.

Discussion is offered in the form of a symposium on dispatching organizations of the various member utilities reporting arranged in the following manner:

1. Justification for dispatching organization.
2. Organization, personnel qualifications.
3. Authority and responsibility.
4. Scope of work.
5. Safety methods.
6. Regulation of load, voltage and frequency.
7. Handling of company interchange of power.
8. Looking ahead: (a) The future office.
   (b) Service requirements.
   (c) "Super-power" connections.

* Report of subcommittee of electrical apparatus committee—H. W. Neir, chairman.

Justification For Dispatching Organization

It is an established fact that centralized control is a vital necessity to all organization. To survive the public criticism of some of our common practices it is essential that any new methods developed along operating lines must perform the necessary services in keeping with constructive criticism and institutional policies and must accomplish the desired ends with economic results. The historical background of development of system control is such that the present dispatching organizations represent as near the ideal as human ingenuity and economic consideration will permit.

Organization, Personnel Qualifications

The organization of a dispatching department follows more uniform lines than does other operating units in that it comprises a small compact group of specialists who function within definite limits and whose head reports directly to the executive of the operating division or department. The essence of the plan is to centralize control under one strategically located office. With the expansion of some of the larger companies it has been found expedient to delegate the operation of certain portions of the system to sub-dispatching offices located at points where communication channels are more free of disturbance and where intimate contact may be had with local conditions. When the point of growth has been reached at which work of the sub-dispatching office cannot be cared for adequately, the delegation of authority under nominal supervision is extended further by establishment of "switching centers" at "key" stations to which is given the responsibility of directing the operation of a small group of lines and stations so situated and connected that the system is not dependent upon the facilities represented for its operation. Sub-dispatching offices and switching centers, except in moments when communication is lost, get authorization from the central dispatching office in all important dispatching matters. Written emergency orders at each station provide for resumption of local service if station is unable to receive instructions from controlling dispatching office or switching center.

One of the smaller companies, whose system layout will permit, has two control stations each handling an integral part. These control stations operate independently their respective division or co-ordinate their operation as a unit by mutual effort. They do not form a separate dispatching department, but are supervised in these matters by the operating superintendent. This company is considering the establishment of a dispatching organization along orthodox lines.

In appraising one dispatching organization scheme against another it is urged that great value be placed upon communication facilities available in relation to the system physical structure. The problem of communication is one of the essential features in the work of a dispatcher. Power companies have found telephone company channels slow or unsatisfactory in many instances and have been forced to build their own communication system. Wire, radio, carrier telephony and telegraphy, and supervisory control by wire and carrier are in use at the present time, none of which may be said to be absolutely dependable under all conditions. However, it would appear that an application of wire and carrier telephony, and a restricted use of supervisory control are best suited to the job.

The qualifications of a dispatcher must of necessity be of a high order in that his ability and knowledge are reflected to a great degree in the character of service rendered to the company's patrons. A dispatcher should be conscientious and ambitious. He should be a man of good morals, be physically fit and have regular habits. A technical education is a good attribute, although not essential. At any rate he should have a thorough understanding of power house and substation operation and an intimate knowledge of the system which he controls—the capacities and limitations of its various elements. Keen perception and ability to think and act quickly are indispensable. He should be tactful and should be in sympathy with company policies which affect him or his work. His personality should be such that he is well met and well liked. He should be able to handle properly the clerical details of his office.

A high grade of work is demanded of the dispatchers, as specialists, and due consideration must be given in the selecting of their personnel and the building up around this organization of a bulwark of friendliness and confidence so necessary if the morale and efficiency of the department are to be maintained. In addition consideration should also be given to office conditions, health, recreation, salary schedules compatible with responsibility and authority.

Authority and Responsibility

The dispatching organization has operating supervision over the essential physical properties utilized in system operation and is charged with the responsibility of operating these several elements in such a manner as to promote continuity of service in a safe and efficient manner. Under emergency conditions this authority may extend to the direction of personnel outside of the operating department or division should the situation warrant. Most companies incorporate such instructions in their "rules and regulations" published for guidance of employees.

Scope of Work

Production, transmission and interchange of power with other systems are matters of first concern to all dispatching organizations. It is common practice with relatively small systems to have their dispatchers handle all lines and apparatus of voltages ranging down to 2.2 kv. a.c., and also to handle the d.c. feeders. Larger systems set up their dispatching organizations to handle direct through central and sub-dispatching offices only those lines of 30 kv. and above, with nominal supervision of voltages in the band between 30 kv. and 10 kv. which are controlled by switching centers. Exceptions are made of certain interconnection ties and of important industrial circuits of voltages as low as 10 kv. that are under direct charge of central and sub-dispatchers. Other exceptions are that switching centers under dispatching office supervision direct the operation of transmission lines up to 60 kv. as noted under the second subhead.

Jurisdiction is had over allocation of load demands to the various sources, the regulation of voltage, frequency and power factor, the switching of lines and apparatus and the application of safety measures instituted for the welfare of employees and the public. The control of relays and other protective devices are within the dispatcher's province, although normal adjustment thereof in some cases is authorized by an engineer outside the dispatching organization.

A considerable part of dispatching work is the keeping of operating and statistical records. There appears to be no standard way of compiling such records, each company using methods as seems to best suit its particular needs. The dispatching department of one company carries its paper work to the point of making voluminous studies of troubles classified as to voltage, cause, seasonal occurrence, geographical location, etc. This is valuable information, but is not strictly a dispatching problem, falling more under the category of maintenance. Another company requires its dispatchers to keep a complete record of maintenance and construction progress, including auditor's accounting numbers. No doubt there are economies effected in administrative expense by having dispatchers employed at what might otherwise be leisure moments. There is danger, however, of so loading the dispatching department with non-essential detail that insufficient time is available for study of real dispatching problems involving much greater possibilities for economy.

It is usual practice to keep a log of all switching operations, disturbances and other transient matters, and to maintain a production sheet containing such information as is necessary for the proper handling of the load. Daily report to the management is made of interruptions, load demand and output, steam-plant efficiencies, stream flow and reservoir levels, precipitation, maximum and mean temperatures, load factor, etc. Other data are assembled for load distribution and power factor studies.

Safety Methods

It is not generally understood that an electric system is the most powerful concentration of energy outside the forces of nature, and that the means of detecting the presence of an electric circuit are quite limited. Consideration of these inherent features enables one to appreciate the grave responsibility that accompanies system control and emphasizes the necessity for stringent safety rules and their strict observance. Regulatory bodies, cognizant of apparent dangers, have promulgated certain rules which are, in effect, law. These are supplemented by individual company regulations. In dispatching work involving the loading of equip-

ment, switching and issuance of clearances, the underlying requisite is **safety.**

It is common practice for parties wishing to work on conducting apparatus to get a clearance from the office having dispatching jurisdiction. Before giving this clearance the dispatcher determines that the man calling for a clearance is a responsible person authorized to call out such apparatus, that the system facilities will permit the apparatus being spared for the period wanted, that the work to be done is necessary, and that other departments having maintenance supervision over immediate adjuncts to the apparatus are notified of the program so that the maintenance outrage may be kept at a minimum. The apparatus is isolated from all energy sources by the opening of oil circuit breakers, disconnect switches, pole-top switches or jumpers, and protective grounds are placed thereon. Clearance then is issued direct to the man in charge of the working detail with an explanation of switches open and location of protective grounds. The party repeats verbatim the clearance received, proceeding with the work. The dispatcher logs the transaction and directs "Men at Work" tags to be placed at all points from which apparatus might be energized. When work is completed the party receiving clearance personally surrenders it to the dispatcher, stating the then present condition of apparatus. Protective grounds then are ordered removed, and when this is reported as having been done, the apparatus is restored to normal operation. The procedure is carried out in a very formal manner with names of all persons involved recorded. Clearances are not usually given for purposes of repair unless trouble has been located and facilities are available for immediate work. Parties holding clearances are responsible for all men working under their supervision. Clearances must be surrendered direct to the point of issuance and by the recipient.

Both routine and emergency switching offer many hazards which always must be borne in mind, such as the overloading of equipment or lines, the adjustment of voltages when paralleling, the synchronizing of portions of systems out of phase, the grounding of energized equipment, the breaking of parallels on air-break switches, etc.

Regulation of Load, Voltage and Frequency

Allocation of load to the several production sources is strictly an economic consideration. Most Western companies have both hydro and steam plants. Those water-power plants having little or no storage facilities are loaded according to stream-flow values, this being considered "base power." Where reservoirs are provided, the division of load between hydro plants and steam plants is in accordance with relationship of system load to system generating capacity and seasonal run-off estimates, emergencies excepted. Reserve generating capacity kept floating is a matter for individual company discretion, but is governed by load requiremets, size of units operating, remoteness of principlal supply to load centers, etc.

The normal inverse ratio of voltage to load demand makes necessary some means for correcting voltage fluctuations occurring on daily and seasonal cycles. The situation is confounded further on systems having sources of power located at opposite points, such as hydro plants in the back country and steam plants at tidewater. The usual operating practice is to supply a transmission voltage of such stability as to permit the distribution circuit voltage to be kept constant by the substation regulator or condenser range. Daily fluctuations are adjusted by regulation at power houses and by the operation of synchronous condensers. Seasonal variations are handled in the same manner and by the change of transmission and distribution transformer taps.

Frequency regulation on the single system is maintained by the plant designated by the dispatcher. This plant should have relatively large units as compared to prevailing load swings. Speed control of interconnected systems can be handled successfully only by one of the connected companies assuming regulation. The remaining systems in the group gage their respective production quantities by the amount of exchange desired over the connecting ties. Much attention is being directed to refinement of governors and speed regulating devices on prime movers. Popular use of electrically-driven clocks has increased the necessity for this improvement.

Handling of Company Interchange of Power

Economic resources of the Pacific Coast as related to seasonal and geographical diversity of electric power demand are not being exploited to any great extent. Contracts for the interchange of power are executed between the managements of companies involved and the details of effecting the exchange are carried out by the several dispatchers according to the stipulations thereof. Emergency calls for assistance are handled at the discretion of dispatchers in accordance with resources available, a matter in which a splendid spirit of co-operation has been exercised.

Interconnections between systems of the same frequency are attained by direct line ties operating in parallel, by the transfer of operating plants from one system to another, and by the switching of station load to the supplying system. Exchange between the 50-cycle group in the South with the surrounding 60-cycle systems is by means of frequency-changers operating either in parallel or carrying a separate load, and by the change-over of production units to operate on the receiving system at the desired frequency. Of these methods only the parallel of systems has offered difficult operating problems, among which are the following:

Adjustment of voltages satisfactory to both systems, i.e., the control of exchanged kva.
Hazard of synchronizing and of maintaining proper synchronizing current between large systems over light ties.
Regulation of load exchange.
Stabilization of frequency.
Division of load between frequency changers operating in parallel.
Metering.

These problems have been solved in a practical way by Western companies. It has been interesting to read discussions from a theoretical standpoint on load exchange and frequency control of amalgamated systems under so-called "super power" connections, and to compare the conclusions with the interconnection experience of local systems.

One Example Is Cited to Illustrate

During the dry year, 1924-25, corporate and municipal utilities and isolated plants operating in California and Nevada were interconnected, representing in excess of 1,000,000 kva. in 86 generating plants of from 150 to 90,000-kva. capacity with units ranging in capacity from 150 to 45,000 kva. As a power conservation measure it was decided to lower the frequency one cycle as a test to observe the effect, and then if found beneficial to operate at the lowered frequency during the period of power curtailment. The double operation of lowering and raising the frequency was accomplished twice at predetermined times with no difficulty whatever. In fact the incident was not looked upon as a notable achievement by these interconnected companies for previous experience in interconnection had indicated that it was a simple operation.

For a number of years one company has been operating in parallel through frequency-changers a portion of its system at 50 cycles and the remainder at 60 cycles. At present the 60-cycle portion has four power plants of 10,000 kva. capacity and is connected to the larger 50-cycle system of 20 plants having 719,200 kva. capacity through two 15,000-kva. frequency-changers located at one station and one 30,000-kva. frequency-changer at another station. Probably every interconnection combination possible has been experienced. A workable solution for all problems encountered has been satisfactorily arrived at.

Looking Ahead

The Future Office—The future dispatching office will be equipped to enable the system dispatcher to envisage operating conditions more quickly, thereby decreasing time delays in routine processes and in resumption of service during truble now considered necessary. The diagram board no doubt will be constructed as a calculating table so that line loadings for any desired switching combination may be forecast accurately prior to the operation. Carrier-current will be the medium for operating various types of indicating or recording instruments from major stations at distant points, among which will be: voltmeters, frequency meters, ground detectors, telemetering equipment giving loads on plants and groups, and water-level indicators on reservoirs.

Similar equipment will be employed to give large production groups voltage and frequency indications of

other such groups, that in event of split-up of a transmission network the situation may be handled more expeditiously. The possibility of furnishing each station with synchronized time is not without the scope of reality.

Communication systems will be reinforced materially. Leased and privately owned telephone lines, and carrier superimposed on both telephone and power lines will form the principal channels. The radio situation is far from satisfactory for this work and the immediate future promises little for its betterment. A device is now being perfected to record complete telephone conversations. Its practical application would eliminate disputes as to orders given and received, and would be of much value in analysis of trouble. Automatic selector equipment arranged to accommodate manual code-ringing will bring to the dispatcher's telephone board only those calls intended for him and will hold them until answered. Special indicating lamps on his telephone board will indicate by telephone-line inductance the portion of the system on which an electrical disturbance occurs.

Service Requirements—As the application of electrical devices at factory, farm and fire-side becomes more pronounced, in just this degree does the supplying system's responsibility for uninterrupted service increase. Happily there are few or no penalty contracts in effect on the Pacific Coast, yet the mirror of public opinion as well as loss of revenue impel the employment of the best engineering skill in devising adequate methods and equipment for service betterment. Development of circuit breakers of increased interrupting capacity or use of current-limiting apparatus are becoming imperative if loop operation is to be continued, the alternative being the radial transmission and distribution scheme, an expensive substitute when properly laid out.

Protective relays have advanced wonderfully in the last few years, but their inherent limitations coupled with the inertia of switch mechanisms cause many costly and apparently unnecessary interruptions in involved networks. Line insulation and construction is adequate with perhaps more attention to routes. Time was when electricity was a luxury. It is indispensable now, so much so that an interruption of only short duration causes industrial losses, traffic confusion and often real hardship.

"Super-Power" Connections—There are very few indications on the immediate horizon of the possibility of exchange of power between systems in amounts of consequence except as prompted by financial merger of properties, since present systems are being developed into self-contained units. It is expected that the Colorado River project will give an impetus to such an arrangement. The radius of economic distribution from this source probably will not incompass steam production which it may replace in sufficient quantity to absorb its output if completed within the next few years. At any rate the psychology of its inception will create wide-spread interest and result in the general proposition of "super-power" as applied to far Western states to be fully explored.

If and when these connections are realized it is not stretching one's imagination to suppose that the detail of interchange will be administered by a super-dispatcher who will deal directly with system dispatchers.

Transformers and Regulators*

The subcommittee on transformers and regulators was appointed from the membership of the electrical apparatus committee of the Pacific Coast Electrical Association for the purpose of making a study of current practice in transformer and regulator design and manufacture and in the utilization of this equipment, and disseminating the information thus obtained for the benefit of all association members concerned. In making this study the subcommittee has interpreted the word "transformers" as including power transformers only and has confined itself principally to Pacific Coast practices and experiences and developments of particular interest to this territory. It has avoided in so far as possible the duplication of information available in manufacturers' publications, the technical magazines, and other committee reports, merely referring to these when necessary, although some duplication has been practically unavoidable.

The modern transformer (and this statement applies as well to the induction voltage regulators) on the whole is believed to be a reasonably rugged, dependable and satisfactory piece of equipment. Subjected more or less frequently to heavy electrical and mechanical stresses it occasionally fails due either to such stress or to defects in design or manufacture which still occasionally make themselves evident. It nevertheless constitutes a link in the transmission or distribution network which requires comparatively little attention and maintenance and occasions nowhere the concern regarding its performance as does, for example, the oil circuit breaker. As a result of this dependability the general trend of recent development in its manufacture has been rather toward increasing its usefulness to the user through the addition of auxiliary equipment such as tap-changers, conservators and inertaire equipment, and the like, rather than toward radical changes in the electrical or mechanical design of the transformer itself.

The following outline has been used in selecting the subject matter to be included in this report:

A. Selection of transformers.
   1. Water vs. air cooled.
   2. Three phase vs. single phase.
   3. Determination of size of bank.

B. Tap-changing under load, with reference to:
   1. Transmission requirements at points of interconnection.
   2. Distribution requirements.

C. Transformer maintenance.
   1. Methods of conbatting scale formation in cooling coils.
      a. Prevention.
      b. Removal.
   2. Methods of drying.
   3. Repairs and redesign.

D. Experiences of interest.

E. New developments and improvements in transformer design, manufacture and application.

F. Selection of regulators.

G. Protection of feeder regulators against heavy short-circuit currents.

H. New developments and improvements in regulator design, manufacture and application.

Selection of Transformers

The trend of all companies reporting is toward the use of self-cooled transformers in preference to water-cooled, excepting at hydro plants or other locations where water already is available or the necessary auxiliary cooling equipment such as towers, pumps, etc, already have been installed. Among the disadvantages ordinarily incident to the use of water-cooled transformers may be included the necessity for providing a cooling tower, pumps, more or less extensive piping systems and possibly a water softener; providing space for these; the cost of obtaining make-up water, whether supplied from city mains or pumped from a well on the station property; trouble caused by spray from the tower blowing over insulation on adjacent lines, structures and equipment; formation and necessity for removal of scale in cooling coils; and the growth of algae in the cooling tower sump. These disadvantages usually are more than sufficient to justify the slightly increased size, weight and cost of self-cooled transformers over water-cooled, especially in view of the decreasing cost of the former as compared with the latter over the past few years.

A considerable number of water-cooled units still remain in service and others are being purchased for use in locations where conditions warrant their use. Many of the older water-cooled banks, however, are being converted by the addition of radiators or means for circulating the oil through external cooling coils or radiators.

The Southern California Edison Company reports a number of installations in which the oil is circulated. Several methods are used including circulating the oil through cooling coils placed in the tail-race at hydro plants or in a convenient reservoir pumping the oil from the transformers through radiators located on the station roof or other location where the prevailing winds will have better access to them, and the scheme used at the Eagle Rock Substation where fin-type radiators are installed in a chimney and the oil pumped through them. A blower is connected into the base of this stack or chimney and cut in or out of service depending upon the temperature and load conditions. This type of installation has been used successfully in a number of smaller stations as well. This company

* Report of subcommittee of electrical apparatus committee—H. T. Sutcliffe, chairman. P. H. Affolter, Boyd Anderson, M. L. Baden, E. R. Battey, C. F. Benham, L. A. Buese, A. W. Copley, D. J. Kelly, R. D. Likely, W. C. Smith.

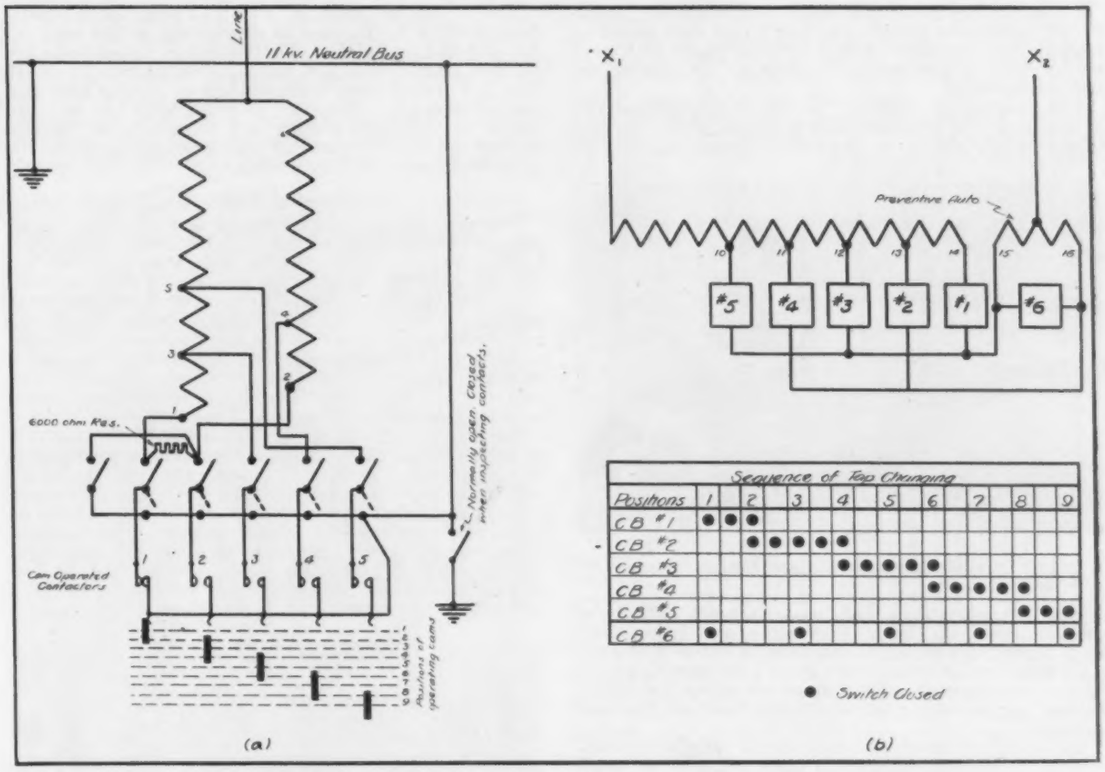

Fig 1. Schematic diagram of tap changers on a transformer.

reports the use in several of their later installations of larger units equipped with auxiliary blower equipment.

The Pacific Gas and Electric Company circulates the oil through external coils at two of its stations and also has used the scheme of circulating water through a closed system in order to prevent the formation of scale within the transformer cooling coils. Auxiliary air cooling has been resorted to to increase the capacity of existing self-cooled banks, contact-making thermometers being arranged to cut the blower in or out of service depending upon transformer temperature. At one unattended station one of these thermometers is connected to trip out one of the feeders in case of excessively high temperature due to the blower equipment going out of commission or other cause, thereby relieving the load on the bank and preventing its damage. Indication of such tripout is given by loss of voltage on this circuit. This company during the past three years has equipped a large number of transformers with radiators for self-cooling, in sizes up to 1,800 kva.

The Southern Sierras Power Company follows the general practice of purchasing transformers in sizes of 500 kva. and above, self-cooled but equipped with water cooling coils where there is a possibility of ultimately utilizing the additional resulting capacity. This practice has been resorted to in occasional instances by other member companies reporting.

As between 3-phase and single-phase transformers, all companies reporting express a general preference for single-phase units primarily because of the greater flexibility of the single-phase installation. Very few 3-phase power transformers are reported, particularly in sizes above 300 kva. The 3-phase transformer possesses certain advantages in that it requires less space, a smaller overhead structure and foundation, and may cost less than three single-phase units of equivalent bank capacity. The efficiency of the 3-phase unit is higher and more uniform under varying load. A greater increase in the self-cooled rating can be effected through the use of air-blast on the 3-phase than on the single-phase transformer. On the other hand, the use of single-phase transformers permits the installation of a spare unit with selective switching equipment, providing at the same time a spare phase for emergency use and the possibility of removing from service one unit at a time for cleaning, testing, cleaning water coils, or general maintenance work. The transformers are smaller and easier to handle.

It is impossible to make a general statement regarding comparative installation costs due to the fact that the cost of associated switches and incidental equipment will vary according to the particular job under consideration. From such reports as have been submitted, however, it would appear that the single-phase installation is considered the most economical and/or satisfactory in the majority of cases.

A study recently was made by one utility in connection with the proposed building of a new 11/4-kv. delta-star connected city substation which was to have an initial capacity of 7,500 kva. and was to be supplied over two cables from the 11-kv. network. Additional 7,500-kva. banks and supply cables were to be installed as the load required. Choice lay between two 7,500-kva. 3-phase banks or one single-phase bank of like capacity to begin with. In the former case no switching was required on the high side as each bank with its 11-kv. cable would have sufficient capacity to carry full load, while in the latter case three oil switches with disconnects for transferring load and cutting in the spare transformer would be necessary. Additional banks similiarly would require switching facilities on the high side of single-phase banks, but none for 3-phase banks.

TABLE I—Rough comparison of 3-Phase vs. Single-Phase Banks.

	7,500 kva.		15,000 kva.		22,500 kva.	
	1-Phase	3-Phase	1-Phase	3-Phase	1-Phase	3-Phase
Transformers	20,500	28,750	35,875	43,125	51,250	57,500
11-kv. bus and selector switches	1,800	.....	2,500	.....	4,000	.....
Difference in cost of oil switches, cells, etc.	6,000	.....	12,000	.....	18,000	.....
Comparative overall costs of installation	28,300	28,750	50,375	43,125	73,250	57,500

In each case one additional low-tension switch would be necessary for the 3-phase layout. A comparison of estimated costs, roughly itemized, for the two schemes is given in Table I.

From the foregoing it appears that while the single-phase installation in this particular case would be slightly less expensive initially, the 3-phase scheme would effect a considerable saving as the size of the station increased.

The problem of selecting the size of transformers to be installed at a given location is simple where the load is definitely fixed, as at generating plants and certain

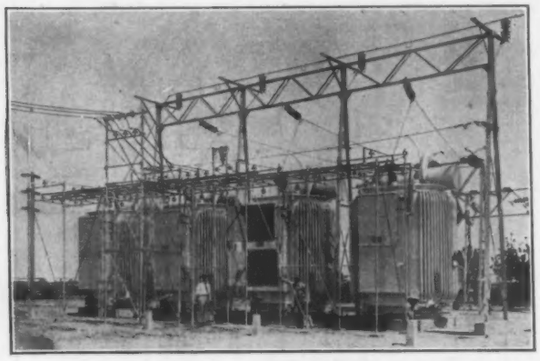

Fig. 2. A transformer bank equipped with tap changers.

classes of substations, but becomes more difficult of solution when the bank is to serve a growing load. Most reporting companies endeavor to figure ahead not more than two or three years due to the uncertainty of future requirements, planning on replacing the transformers or installing an additional bank as the load increases.

The shuffling about of banks due to increasing loads results in the accumulation in stock of those of small capacity, particularly on extensive systems, and the utilization of these transformers has proved somewhat of a problem. Practically the only outlets lie in the installation of new stations of small capacity and the installation of additional banks at existing stations. The latter alternative offers the greater possibility of utilization and in addition has an advantage in the case

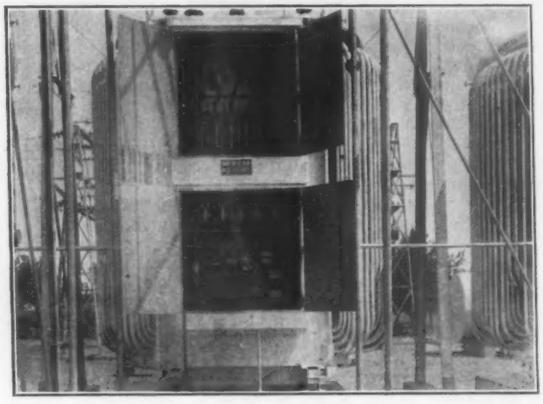

Fig. 3. Interior of housing for contactors and similar equipment.

of substations serving agricultural load in that one bank may be cut out of service during the greater portion of the year, thereby affecting a saving in transformer losses.

The Los Angeles Gas and Electric Corporation reports the purchase of banks of 5,000-kva. capacity because of adaptability to the sizes of their substations, usually 15,000 or 20,000-kva. capacity. Flexibility in case of trouble is secured by this practice. Substation secondary buses are sectionalized with a transformer bank on each section and reactors between adjacent sections. One spare bank is kept available for use at any one of several city stations.

The Los Angeles Bureau of Power and Light similarly standardizes on sizes and simplifies the spare problem still further by keeping one spare single-phase unit available for use in several banks.

These two methods of providing spare transformer capacity for use in emergency would seem to be both economical and effective where substations are located closely together, as in urban territory; where they are served from transformers of similar type and rating; and where they are provided with two or more banks to insure flexibility and continuity of service during the time required to transport the spare to the substation and cut it in service.

Tap-Changing Under Load

The use of tap-changing equipment at the points of interconnection between the systems of contiguous utilities seems, so far, to be largely confined to the eastern part of the country, whereas the use of such equipment for the control of feeder regulation finds more application in the West. Both of these conditions are due largely to the closer interconnection of smaller, more densely loaded systems in the East, as compared with the existence on the Pacific Coast of more extensive systems supplying lighter concentrations of load over long feeders requiring close regulation.

To date, Pacific Coast utilities have not made a practice of including in their contracts (covering power sale or interchange with adjacent utilities) clauses relative to the power factor at the point of interconnection. This probably is a major factor in the absence of tap-changing equipment at such points. It would seem that some consideration should be given to the control of wattless current at such points, however, as the flow of such current in relatively large amounts materially affects the investment in lines, transformers, etc.

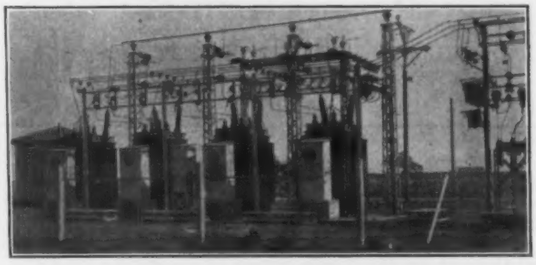

Fig. 4. A completed installation of automatic tap changers.

necessary to effect such sale or interchange. It is conceivable that in many cases the overall cost of establishing the interconnection point might be materially lessened by the employment of tap-changing or other suitable regulating equipment.

In one concrete case upon which a report was received from a Pacific Coast company a connection existed between the systems of two utilities, which for the purpose of this discussion will be designated as "A" and "B" companies. During two successive months the deliveries were as follows:

"A" to "B"	4,465,962 wattless kva.-hrs.
	945,000 kw.-hrs.
"B" to "A"	500,000 kw.-hrs.
"A" to "B"	3,998,322 wattless kva.-hrs.
	243,000 kw.-hrs.
"B" to "A"	5,130,000 kw.-hrs.

During one day of this period "A" company was delivering power from 11 pm. to 1 am. at a maximum power factor of two percent. From 1 am. to 11 pm. "A" company was receiving power, but delivering wattless kva. at a zero power factor. Sometime later "B" company installed a synchronous condenser at the interchange point, after which the power factor of delivery improved, but not to an entirely satisfactory degree.

The above undoubtedly is an extreme case, but is illustrative of the need for control of the flow of wattless current at such points by contractual arrangement if investments are to be kept at a minimum. The means taken to effect this control then will depend upon the ability of the receiving system to absorb its own wattless current if voltages are properly regulated at the point of interconnection by means of tap-changing equipment.

Comparatively few of the utilities included in the Pacific Coast Electrical Association have made use of tap changing equipment. The Southern California

Edison Company reports the existence of several points on its transmission system where tap-changing under load would be desirable and has ordered the equipment for one installation. Another is under active consideration and is expected to materialize within the ensuing year.

Equipment installed to date by the San Joaquin Light and Power Corporation for changing taps under load has been applied only to the regulation of distribu-

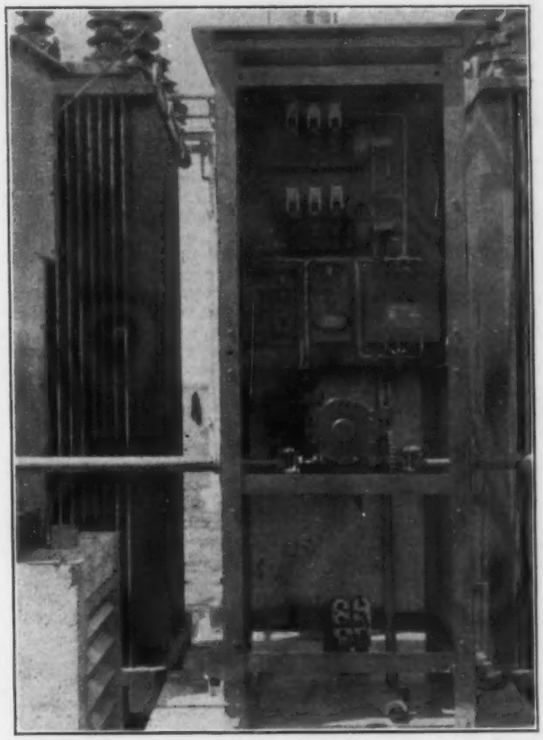

Fig. 5. Interior of one of the control cabinets shown in Fig. 4.

tion voltage on the substation bus. This company has had in operation for some time three installations on 5,000-kva. banks in which separate regulating transformers with approximately 15 per cent boost only in six 2½ per cent steps were employed. The tap-changing is accomplished by means of oil switches and reactors, the middle point being connected to the neutral end of the star winding and the bridged positions being used as operating steps. As these equipments are hand operated only rather coarse regulation is expected. The fact that the steps are unequal and the larger step greater than expected was not considered of importance. The actual steps are alternately approximately 3 per cent and 2 per cent instead of 2½ per cent.

The next installation made was at the Weedpatch substation and previously has been described in detail. This was to have eight 2½ per cent steps on the secondaries of the main transformers. No restrictions were made as to the type of tap-changing equipment. The manufacturer suggested a winding having a small part of the neutral end forked with five mechanically operated air-break contactors. This equipment was furnished excepting that it was found necessary after the order was placed to duplicate the entire secondary winding. This made the transformers much heavier and probably more expensive so that this scheme probably will not be used again although it is giving satisfactory service, the only disadvantage being that the additional weight added slightly to the cost of installation. These transformers at no-load give actual steps of 3¾ per cent and 1⅔ per cent instead of 2½ per cent. The steps are more nearly equal at ⅔ load although an opportunity has not yet been afforded for observing conditions at full load. The fact that one step is larger than the specified value makes it necessary to set the contact-making voltmeter for about 2 per cent each side of normal whereas the specified value would have permitted settings about 1½ per cent on either side of normal. Since this bank serves a rural territory and it is possible to maintain the voltage consistently within 2 per cent of normal this condition is not considered particularly objectionable.

Figure 1a shows a schematic diagram of the tap changing arrangement and Fig. 2 shows a view of the complete bank installed. The mechanism is very simple and has given little trouble so far. During the first seven months of operatior, the contactors operated about a thousand times and appear to be good for at least an equal number of additional operations. Figure 3 shows an interior view of the compartment housing the contactors, disconnecting switches, etc., on one of the units. It may be noted that the motor mechanism for operating the contactors is mounted in one of these compartments. The suggestion has been made that if it were mounted separately it would not have to be moved when that particular transformer was to be taken out of the bank.

This company now has on order for Taft substation four transformers having 5,000-kva. 7,880/13,630-volt star windings with eight 2 per cent steps downward. The method of tap changing is schematically shown in Fig. 1b. All of the switches including the one for short circuiting the reactor will be mechanically operated contactors very similar to those at Weedpatch. The reactor will have an iron core and will be mounted inside of the main tank. Disconnecting switches will be furnished as at Weedpatch to isolate the contactors for inspection. This equipment with the short-circuiting switches is guaranteed to give steps within about 1.8 per cent and 2.2 per cent of normal bus voltage.

The Pacific Gas and Electric Company has no tap-changing equipment in use for the control of transmission voltages, but has made a practice for the past 20 years or more of regulating secondary voltages under load by this means. Many such installations are in

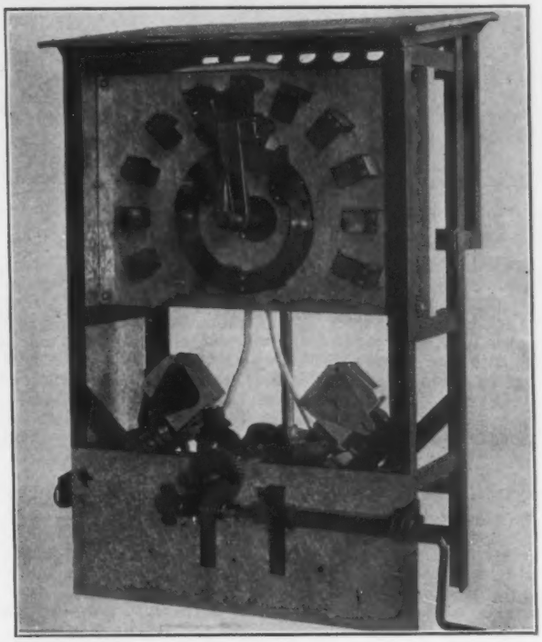

Fig. 6. Close-up of tap changer equipment of Figs. 4 and 5, 300-amp. capacity.

service at the present time. The earlier equipment was manually operated, the first automatic installation having been made in 1921 at which time this company started building its own tap changers. It is building them in sizes of 300 and 1,000 amp. for regulating secondary buses operating at 2.3 kv. delta and 4 and 11-kv. star. Line drop compensation is included. A completely automatic installation of this type has been found to be considerably less expensive, in sizes manufactured to date, than any other equipment available. With the exception of a few minor mechanical difficulties which have been corrected results have been en-

tirely satisfactory. Between 15 and 20 automatic installations now are in service.

The operation of this equipment was described in the 1925 Proceedings of the Pacific Coast Electrical Association and with the exception of a few minor details this description still applies. The equipment also was mentioned in the 1927 report of this subcommittee, in which was described an installation utilizing regulating transformers for the purpose of securing the necessary taps. Such an application is the exception rather than the rule, it being general practice to purchase power transformers for such installations with separate regulating windings on the same core as the other windings. Such regulating windings ordinarily are furnished with a rating of ten per cent of the secondary voltage, divided into five steps of two per cent each. Eleven secondary voltages thus are made

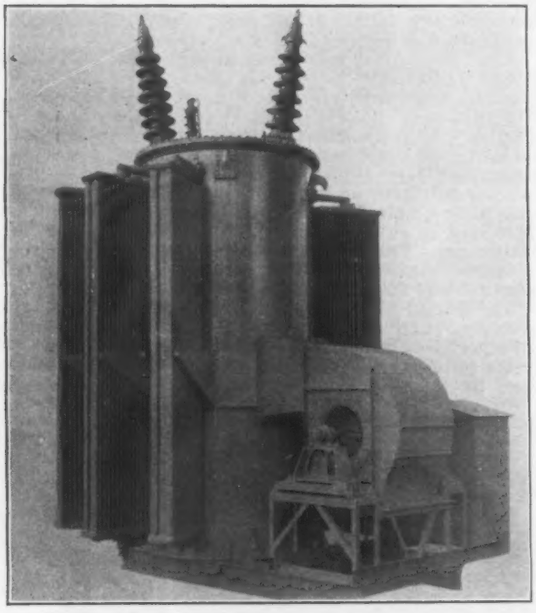

Fig. 7. Individual blower equipment.

available, five boosting, five bucking and one neutral, giving an overall total regulation of 20 per cent, in equal steps of two per cent each. Since these power transformers usually are wound for 2.4 or 7.2 kv. secondary, the regulating winding also is so arranged that it can be used for either of these voltages, resulting in a widely applicable and economical unit. Figures 4, 5, and 6 illustrate respectively the complete installation, the interior of the control cabinet, and a closer view of one of the tap-changers with the cover removed.

Transformer Maintenance

The formation of scale within the cooling coils of water-cooled transformers may be prevented, or at least materially lessened, by securing a supply of water relatively free from hardness by the treatment of water in water softeners, or possibly by the use of compounds similar to those used in the treatment of boiler feed waters. Successful application of the latter method is somewhat open to doubt at least in so far as reports received by this subcommittee indicate, due to the difference between conditions encountered in boilers and in transformers.

Water softeners are in fairly general use on the Coast, although objection has been made to their use on account of their cost and the troubles encountered in their operation and maintenance. One report received indicated considerable trouble with both manually regenerated and automatic softeners, especially the latter, necessitating frequent repairs and adjustments. Mechanisms have a habit of getting out of order, or diaphragm valves stick or do not function properly, resulting in the passage of hard water or brine into the circulating system. In certain instances brine tanks have overflowed over the substation floor.

If water is to be kept soft it is necessary, in addition to operating the softener, to change the water in the cooling tower sump periodically in order to eliminate hardness which accumulates from dust and other foreign matter in the air and may result from the slow dissolving of scale already present in the circulating system, and which concentrates due to evaporation in the tower. One utility reports having tried to accomplish this result by circulating a certain proportion of the sump water through the softener. After a period of time it was found that in all cases where this had been done the mineral in the softener had become coated with a scale deposit, rendering it inactive and necessitating washing in dilute acid to restore its original properties. The reason for this action was not definately determined, but the practice was discontinued after which no further difficulty was encountered from this source.

The Pacific Gas and Electric Company has tried the use of certain boiler compounds, with apparently satisfactory results, the use of these being far less expensive and less troublesome. In an attempt to determine the actual practical value of a water softener and of one of these compounds test runs now are being conducted on two banks of large transformers, the cooling coils of both of which were thoroughly cleaned with acid prior to commencement of the test. A water softener is being used in one case and the compound in the other. Test sections of pipe are provided which will be examined at intervals over a period of several months. The formation of considerable scale, when no preventative measures are taken, already has been demonstrated quite satisfactorily at both of these locations.

Acids are in general use for the removal of scale, sulphuric, hydrochloric, and a commercial acid compound being used in different localities. Centrifugal pumps for circulating the acid are most common, these usually being built of bronze or tinned cast iron for the purpose. One company reports the use of plunger pumps made entirely of Monel metal, including check valves. Experience with these has been very satisfactory, and two have been in use over an extended period of time with but little evidence of wear or corrosion. A

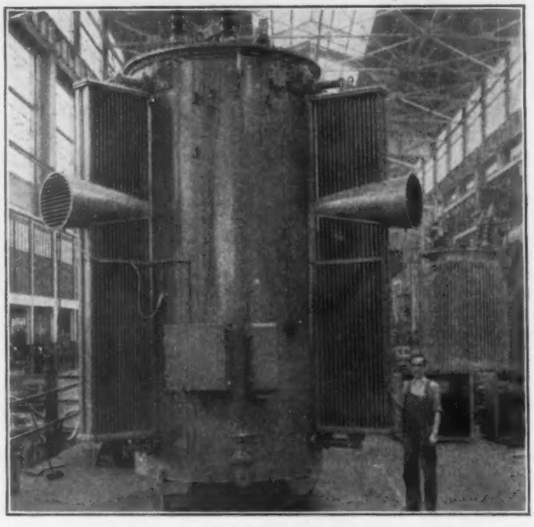

Fig. 8. A "hood-type" air circulating system.

relief valve is provided to relieve the pressure resulting from possible blocking of the coil with dislodged scale.

Drying of core and coils usually is accomplished by circulating current through the windings, by hot air, or a combination of these methods. From two to ten days is required. No company has reported the drying of the transformer under oil, a disadvantage of this method being the length of time required to obtain desired results. The Southern California Edison Company reports having dried certain recently purchased transformers by means of vacuum applied directly to the tanks, and is now equipping its test department at Alhambra with a large vacuum drier with the expectation of doing most of its drying there before the transformers are shipped to the job. Good as well as poor

results have been obtained by shipping new transformers from the factory sealed in oil, it having been necessary in some instances to repeat the drying process upon receipt of the transformers.

Each utility makes a practice of handling its own repair work in so far as economically possible. It is natural that more of this work is carried out by the utilities' own shops on the larger systems than on the smaller, the latter finding it more economical to rely upon manufacturers' or other repair shops when the occasion for a large job of this nature arises.

The Southern California Edison Company is in a position to carry out any type of repairs from a minor trouble to a complete rebuild. Old-type units have been redesigned, indoor covers and bushings replaced with the outdoor type, and radiators added to transformers in sizes below 3,000 kva.

The Pacific Gas and Electric Company in its transformer shop has also carried out considerable routine redesign and rebuilding, particularly on units of older types which have seen considerable service, and finally failed or needed repair. In such cases coils, insulation, spacers, blocking and barriers are modernized, tap-changers or new taps may be added, or the transformers may be equipped with outdoor covers and bushings, radiators to replace water coils, regulating windings, etc. A recent job of this sort involved seven 4,000-kva. transformers and was carried out in the field, completely new coil stacks being designed and installed to provide better insulation, more rigid bracing and increased oil circulation. It has been found possible in

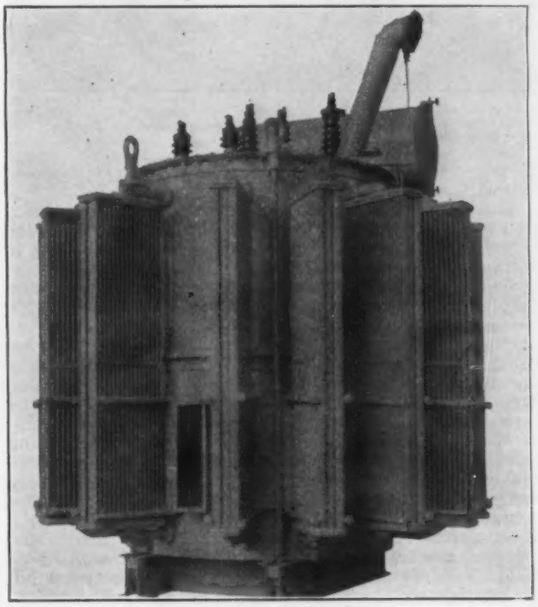

Fig. 9. A unit recently put into service in southern California.

many cases to re-rate transformers to which radiators have been added, the new rating being determined by heat run, plus a liberal margin of safety. Increases in rating from 20 to 60 per cent have been made, depending upon the size and design of the transformer. Radiators have been added to transformers up to 1,800-kva. sizes.

Experiences of Interest

Complaints received from two sources deal with foreign material found in transformers upon receipt from the factory, supposedly ready for service. Specific cases include the finding of a pair of scissors taped into the winding, a case knife embedded in the laminations, a package of cigarettes cached in the windings, overalls, rags and tools found in the bottom of tanks, etc. New transformers shipped in oil usually are drained and subjected to a thorough inspection for loose bolts, foreign material, and shifting of parts in transportation before being placed in service.

Three companies report trouble with leakage through brazed joints of copper water cooling coils after the coils have been cleaned with acid. In a particular instance the coils of three banks of 4,000-kva. transformers were cleaned after which an average of from 15 to 20 brazed joints per transformer out of a total of 30, developed leaks. All of the brazed joints were cut out and copper-welded instead. The same remedy was adopted on several other banks and the results were so satisfactory that the company involved adopted the practice of similarly replacing brazed joints in all water cooled transformers coming into the shop for overhaul. The matter was further taken up with one of the largest transformer manufacturers who, after investigating the method used and the results obtained has announced standardization of this type of joint. In cutting out brazed joints it was noticed that they often were partially clogged with spelter, reducing the effective area by as much as one-third in some cases, thereby offering an obstruction to the flow of water and to loose pieces of scale which might become dislodged either in service or in the process of cleaning, and furnishing an additional argument against the brazed joint.

Experience with water-cooled transformers and more particularly with the necessary adjuncts thereto is leading a majority of the operating companies strongly to favor the purchase of self or combined self and air cooled units in the future.

Certain laboratory tests made on transformer oil during the past year in an effort to determine the causes of sludging developed the unexpected indication that the amount and quality of sludge formed was governed largely by the presence or absence of insulating varnish on the coils and the kind of varnish used. It previously was common knowledge that but little sludging was encountered in many of the older transformers in which no varnish had been used, but the two facts had not been closely associated. In an endeavor to reproduce as closely as possible the conditions existing in the transformer, four small coils were wound on iron cores, three of these varnished, and each immersed in 650 cc. of a first-class grade of transformer oil. The coils were energized and sufficient current passed to keep the oil at a constant temperature of 100 deg. C. Three kinds of varnish were used,

TABLE II.—Sludging tests on different varnishes.

Kind of varnish used	No. 1	No. 2	No. 3	None
Test duration in hours	689.5	175	497	1,404
Temperature, degrees C	100	100	100	100
Grams of sludge formed	18	29	22	0.6

which will be designated by number only. Results of this test are given in Table II.

In consequence of the above results the matter is being given further attention.

New Developments and Improvements in Transformer Design, Manufacture and Application

The development and increased application of equipment for changing transformer taps under load and of auxiliary air-blast cooling for self-cooled transformers probably are the two most outstanding recent developments of interest to the operating companies on the Coast. It is predicted that equipment of both types will find a rapidly increasing use. The development of the conservator and inertaire equipment also merits reference, although it no longer is particularly new.

Cooling systems for transformers are being given considerable attention at the present time, especially the use of forced air cooling against radiators of power transformers. The use of air-blast cooling on the radiators results in a unit which in point of weight and cost lies between the self-cooled and the water-cooled unit in sizes around 1,000 kw. and above. Usually two ratings are given to such a unit, one with and one without the air blast in operation. The particular field for application is found when the transformer may be used for a large part of the time at a load within its rating as a self-cooled unit, the additional capacity due to the air blast being used to take care of peak loads. Under these conditions the air-blast equipment is used only a relatively small part of the time and the losses due to the operation of the same become only part-time losses.

The equipment for obtaining an air blast against the radiators generally consists of a main duct surrounding the tank wall and supplied with air from a blower

located at one side of the transformer. Extending radially outward from the main duct are projecting elements which carry the air from the central duct to the radiator tubes. These elements extend over the whole width of the radiator and they have either slot or circular openings near the top through which the air blows against the tubes, usually at an angle of about

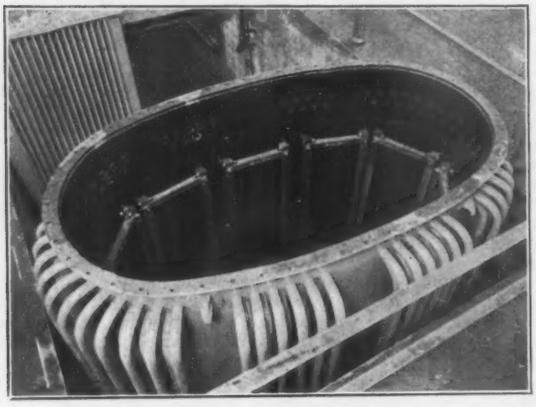

Fig. 10. Interior of a self-cooled tank.

45 deg. upward from the horizontal. Two elements are provided for each radiator, one on either side, so that the two currents of air meet in the center of the radiator and combine to take a vertical direction upwards along the tubes. The upward flow of air from the blower elements draws air along the tubes below the element, furnishing additional cooling. The result is a greatly augmented supply of rapidly moving air over the greater portion of the radiators.

A single blower may be used for a bank of transformers or each transformer may be equipped with an individual blower as shown in Fig. 7. The third type of equipment utilizes an individual blower on each radiator, thus eliminating all air ducts except the small

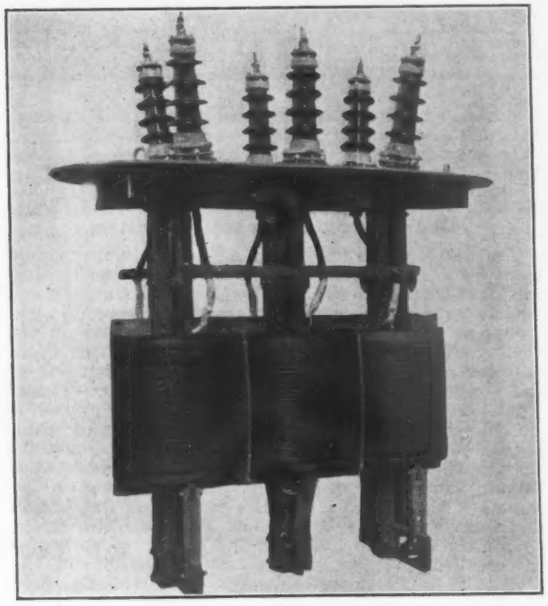

Fig. 11.

projecting element along the radiator. With this equipment, which is designated as the "hood type" and illustrated in Fig. 8, application may be made to old transformers already equipped with radiators only. All of the blowers are controlled as a unit by a double contact-making thermometer mounted in each transformer which is the usual method for controlling blowers used in all forced air cooling installations. The "hood type" equipment has the additional advantage that in case of a motor burn-out only one radiator is affected. Fig. 9 is a photo of one of a bank of transformers recently purchased by the Southern California Edison Company. The increase in the rating of a transformer when air-blast equipment is used will vary from

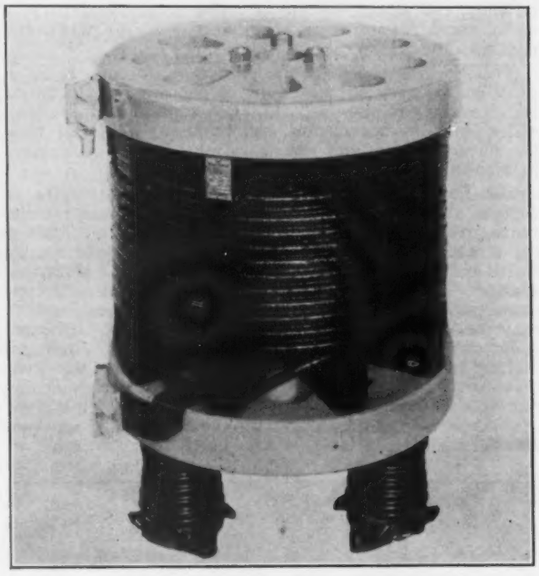

Fig. 12. A current-limiting reactor.

25 per cent to 50 per cent of the straight self-cooled rating.

The development of equipment for changing transformer taps under load undoubtedly has been due largely to the increase in extend of power systems, in voltages employed, and in the increasing use of interconnection between adjacent utilities. After a certain voltage and load has been exceeded, the use of tap-changing equipment becomes less costly than the use of the induction regulator which in the past has become largely relied upon for voltage regulation. The inconvenience and usual impossibility of taking a transformer out of service for the purpose of changing taps has made it further necessary to develop equipment for changing these taps without interrupting service. Many schemes have been used during the past few years, some of them using contactors for making tap changes and others using circuit breakers. Preventative reactors frequently are used for limiting short-circuit currents when the contactors are in the bridging position and similarly are used to make it possible to obtain an additional voltage step between adjacent taps on the transformer windings.

A special application of tap-changing equipment has been made in certain instances for the control of both voltage and phase-angle by utilizing two transformer windings at right-angles (electrically) to each other. The field for this type of equipment is restricted largely to the operation of loops in the transmission network where it may be necessary to adjust both the voltage and the phase-angle at a point where the loop is to be closed in order to reduce or eliminate circulating current. The equipment can be used similarly where a load is supplied over two transmission lines following different routes, to secure such relative distribution of load over the two lines as may be desired.

A number of articles describing the design and application of tap-changing equipment in detail have appeared in recent articles in the technical press. In addition to the 1925-26 reports of the electrical apparatus committee, Engineering National Section Publication No. 256-69 entitled "Transformer Tap- Changing Equipments" which was mentioned in last year's report of this subcommittee, reference is made to a paper appearing in the November, 1927, issue of the Journal of the A.I.E.E. by Arthur Palme entitled "Application and Design of Load-Ratio Control Equipment," another article by L. H. Hill in the same issue entitled "Trans-

former Tap-Changing Under Load," and to an article by L. F. Blume on "Load-Ratio Control," written in two parts, the first of which appeared in the March, 1928, issue of the General Electric Review.

Selection of Regulators

The same arguments which apply in the case of self vs. water-cooled transformers hold in the case of induction regulators with even greater force. A few old water-cooled regulators still are in service, but with few exceptions new regulators are of the self-cooled type. Similarly single-phase units are chosen in the majority of cases because of greater ease in handling and flexibility in operation. A defective regulator may be cut out of service and replaced without interfering with the operation of the remainder of the bank or interrupting the service, whereas with a 3-phase regulator one phase out necessarily means three phases out, and an interruption must occur in cutting the regulator in or out of service. On 2.3-kv. delta systems two single-phase regulators often are installed, leaving space for the third which may be added at such time as the circuit may be cut over to 4-kv. star operation.

Each company standardizes insofar as possible on certain sizes of units although the standards of various companies differ.

Protection of Feeder Regulators Against Heavy Short Circuit Currents

As an indication of practice in the East with respect to the use of feeder reactors for the protection of regulators against excessive short-circuit current, the following extract from the minutes of the Electrical Apparatus Committee Meeting, Engineering Section, Great Lakes Division, held on March 11, 1927, may be of interest:

> Experience data were requested regarding the use of reactors with regulators to limit the short-circuit current through the regulator. The Philadelphia Electric Company has had some regulator failures under short-circuit currents of 100 times full-load current, and now it is that company's practice to limit this current by the use of a reactor to possibly 50 times full-load current. The Detroit Edison Company does not at present install reactors, but is leaving a space for future installation if such seems to be required. The New York and Queens Electric Light and Power Company limits the short-circuit current to 40 or 50 times full-load current. The Commonwealth Edison Company does not install reactors on installations were the short-circuit current is less than 75 times full-load current, but above this value installs a reactor which will cut the current down to approximately 35 to 40 times full-load current.
>
> The Baltimore company experienced a regulator failure in using an instantaneous reclosing scheme on their feeders by breaking the segment of the regulator rotor on the resumption of voltage. It is now that company's practice to install a soft-iron pin which will shear off rather than break the segment itself.
>
> In answer to the question as to whether or not the inherent reactance of the regulator was used in calculating the short-circuit current, the answers varied for using the entire reactance of the regulator (about 2 per cent) down to an arbitrary value of ½ per cent.

Referring back to Pacific Coast practice, The Southern Sierras Power Company reports no feeder reactors in use; the Los Angeles Gas and Electric Corporation installs such reactors where necessary in regulated circuits to limit the short-circuit currents to 25 times the normal capacity of the regulators; the Pacific Gas and Electric Company is providing space in all new urban substations for the installation of 3-phase 3 per cent reators on regulated feeders, the reactors being omitted for the present.

It may be of interest to note that a five per cent reactor installed in series with the feeder may result in only a fraction of one per cent drop in the line voltage, depending upon power factor conditions, due to the wide difference in phase-angle between the line voltage and the drop across the reactor. Thus, reactors of sufficient size to limit possible short-circuit currents to a safe value may be used without seriously affecting line regulation.

One company reports the breakage of motor support castings on 200-amp. regulators due to heavy short-circuit currents. The manufacturer strengthened the castings, but recommended the installation of 3 per cent reactors to prevent the subsequent breakage of other parts, probably the teeth on the worm-wheel segments. It would seem desirable to have the weakest link one that might be the most easily replaced, similar to the use of the soft-iron pin mentioned in the report quoted above.

New Developments and Improvements in Regulator Design, Manufacture and Application

Oil-immersed reactors now are available for outdoor installation and for indoor application above 15-kv. The development of such a reactor contained in a metal case consists essentially of providing means for eliminating the effect of the reactor leakage field on the enclosing tank, so as to prevent hysteresis and eddy current losses in it. Shields can be placed around the sides of the coil leaving the top and bottom unshielded, or the coil may be shielded by the use of a magnetic circuit continuous above, below and on two sides of the coil. The most common method is the side shielding obtained by securing the laminated iron shields to the tank walls. The shield then becomes a part of the tank. This type of construction is shown in Fig. 10 while Fig. 11 shows the core and cover assembly.

In Fig. 12 is shown a dry-type reactor of new design being manufactured for indoor use up to 15-kv. It consists essentially of a hollow cylinder of concrete upon which the cable is wound, the layers being horizontal and separated by means of treated vertical spacers which in turn pass through slots in radial spacers. Concrete discs bolted to inserts in the center cylinder serve to separate the structure and anchor the terminals. The cable with which the reactor is wound is provided with a special heat-resisting insulation of high dielectric strength, which it is claimed results in a high factor of safety against flash-over in addition to protection against pieces of metal being drawn in and short circuiting the coils.

Conclusion

The foregoing report necessarily is somewhat incomplete and it is believed that there is considerable room for further study. Certain subjects touched upon in this year's work merit further investigation and additional subjects, notably transformer and regulator reliability, may be given attention to advantage. Accordingly it is recommended, in concluding, that the work on transformers and induction regulators be continued during the year 1928-9, special attention being paid to the electrical and mechanical reliability of this class of apparatus.

Hydraulic Power Committee Reports[2]

The group of reports presented by the several subcommittees of the hydraulic power committee as the result of the past year's work is one of the most comprehensive and valuable contributions thus far made by the committee to the Engineering Section of the Pacific Coast Electrical Association. Practically all phases of hydroelectric development are covered in some form.

Starting with the first diversion of water from its natural course in the river is the report covering the relative merits of various types of spillway gates on or adjacent to dams. This report deals with all features affecting the choice of suitable spillway gates. It outlines the experiences and practices of member companies and others and is well illustrated with typical examples and pertinent data. The subject has been chosen for a national serial report and the subcommittee personnel has been increased to include a number of engineers from other parts of the United States and Canada, in order that the national report, when published, may be as comprehensive as possible.

[2] **E. A. Crellin,** Pacific Gas and Electric Company, chairman. **H. K. Fox, San Joaquin Light & Power Corporation,** vice-chairman. **California Corrugated Culvert Company:** A. C. Norton. **The California Oregon Power Company:** J. F. Partridge. **General Electric Company:** W. E. Melarkey. **Great Western Power Company:** C. F. Benham, R. E. Ballew, C. M. Mardell. **Pacific Gas and Electric Company:** W. P. Bedgood, L. G. Roberts, J. R. Johnson, E. F. Maryatt, G. H. Bragg, Walter Greyer, B. N. Merritt, Hector Keesling, C. deWitt, I. C. Steel, G. A. Hunt. **Pelton Water Wheel Company:** R. S. Quick, E. M. Breed. **San Joaquin Light & Power Corporation:** C. P. Rhine, R. D. Likely, A. M. Smith, J. W. Jourdan, Oren Reed, H. K. Fox. **Southern California Edison Company:** H. A. Kruger, C. C. Long, C. B. Carlson, O. J. Schieber, Allen Hastings, E. D. Sisney, H. D. Root, F. J. Mills, J. E. White, J. F. Davenport, S. F. Coghlan. **The Southern Sierras Power Company:** C. L. Davis, G. M. Wills, E. J. Waugh. **Westinghouse Electric & Manufacturing Company:** W. L. Winter, P. B. Garrett, H. S. Warren.

Next in order is the report on flumes. This report is of value to all who are interested in flumes, as it covers engineering, construction and maintenance details thoroughly. The water carried in the flumes often contains silt and the removal of silt is covered in the report on silt deposits. This report contains some very valuable experimental data collected at the silting basin of the Kern River No. 3 conduit of the Southern California Edison Company as well as illustrative examples of settlers of various designs.

Pressure tunnels are discussed in the next report. It covers lined and unlined tunnels and has one section devoted to a discussion of failures and partial failures. Two tables are appended to the report which set forth in a very clear manner all of the data concerning nineteen tunnels completed by member companies of the P.C.E.A. These tables should prove of very great value to engineers designing and constructing future tunnels.

From the tunnels water is carried to the power house through the penstocks, and penstock painting has been the subject of an interesting report. The subcommittee on penstock painting is a standing committee which continually collects data. As penstocks are drained and inspected, the member companies report the condition of the pipe and their findings on any experimental coattings which may have been applied in an effort to determine the treatment most suitable to prevent corrosion. These data are consolidated and tabulated and form the basis of the subcommittee's report. The national hydraulic power committee has decided to follow the P.C.E.A. hydraulic power committee's example in the formation of a standing subcommittee on the subject of penstock painting and will issue serial reports from time to time as the accumulation of information warrants.

Another subject originating in the local hydraulic power committee and chosen by the national committee for a report is that of power-house cranes. This subject offers an opportunity for study which will result in economies in power-house design and construction. Most crane manufacturers build cranes for mill and factory installation and a high degree of mechanical refinement is necessary to meet the demands of constant usage. Power-house cranes, however, rarely are used when the plant is once put into operation and such cranes do not need to possess the refinements required of factory cranes. The question of a single large crane as compared to two cranes of half-capacity also is discussed in the report and opportunities for further reductions in cost are pointed out.

The report on automatic and semi-automatic hydro plants covers a subject of timely interest. The equipment for rendering hydro plants completely automatic has been perfected to a high degree and the number of such plants is increasing rapidly. The subject was considered of such importance that the national hydraulic power committee has appointed a subcommittee on the subject with engineers from all parts of the United States to write and publish a serial report covering experiences and practice throughout the country. The cost of automatic equipment usually is low enough so that great economies in operation can be shown by its use through the elimination of attendants at the plant. Furthermore, properly designed automatic equipment will not make mistakes and it never sleeps.

The eighth subcommittee is the standing subcommittee studying mechanical reliability of hydro-electric units. This study was started by the national hydraulic power committee in 1924 and data are being gathered from all parts of the United States and Canada which list the outages of modern hydro-electric units and the reasons therefor, together with other data pertaining to their reliability and availability for service. The local committee received reports on 45 units operating in 26 plants with a total capacity in excess of one million horsepower. The report shows that the units were available for service 96.82 per cent of the time and actually on the line 85.38 per cent of the time. The data collected by the local subcommittee are forwarded to the national subcommittee where they are consolidated with data from other sections and published annually as a national serial report.

The regular meetings of the hydraulic power committee have been well attended, the average number present at each of the twelve sessions held during the year being 27. In addition to the consideration of reports of subcommittees there has been much active discussion of current problems and a general informality at the meetings which has served to stimulate the interest of members and permit the interchange of ideas to the benefit of all present. At the San Francisco meetings, Roy Wilkins gave an interesting talk on the cyclic character of rainfall, in which he advanced the theory that the interval between periods of maximum rainfall was 150 years, and that the last maximum occurred about 1860. Since that date the average annual rainfall has constantly dropped and should not begin to rise again until after 1935. He pointed out that individual years might be unusually dry or wet, but that the accumulative average was dropping continually. This fact is apparent from a study of precipitation records and the question as to how long the continually lowering average was to continue, prompted the investigations undertaken by Mr. Wilkins.

In conclusion, it is urged that all members study the reports submitted by the local hydraulic power committee as well as the serial reports issued by the national committee. These reports contain material and data of great value and represent the combined thought and experience of many engineers working under a wide range of conditions. It may well be that the solution of the problem confronting you is contained in one of these reports.

Relative Merits of Various Types of Spillway Gates on or Adjacent to Dams*

This report is confined mainly to a consideration of the experiences of design, manufacture and operation of spillway gates on dams of operating companies of the Pacific Coast states. Many data have been taken from the 1924 report of the hydraulic power committee of the N.E.L.A. without specific reference. The experience of Eastern and Southern companies will be added to this report to make a comprehensive summary of practice throughout the Uiited States. A national subcommittee on this subject has begun work on a report which it is hoped will be finished this year. The present report was discussed fully at the Fresno meetings, April 4-5, 1928. It is hoped that various members will feel free to offer suggestions and any new information which their companies may have available, especially with regard to weights and cost of gates.

Spillways

Location—The location of spillways is governed largely by topographic conditions, type of dam, streamflow characteristics and ice conditions. They may be at either or both ends of the dam, over the top of the dam, partly on and at the end of the dam, or built in the form of a siphon.

In general it is preferable to locate the spillway away from the main dam because of the erosive action of the overpour. In the case of storage reservoirs this usually is possible because many storage dams are built to the same height as the surrounding ridges and therefore it is possible often to find a saddle through which the spillway can be constructed. If no such saddle exists it becomes necessary to blast a spillway channel out of the rock immediately adjacent to the dam.

At the Davis Bridge dam of the New England Power Company and the Gibson dam of the U. S. Reclamation Bureau, circular, funnel-shaped spillways were constructed. The spill is designed to discharge into a vertical shaft which is connected directly to a concrete lined tunnel. The Davis Bridge spillway is controlled by flashboards which may be removed during floods by tripping a latch. The Gibson spillway is not controlled, but provision has been made in the design so that drum gates may be installed at some later date thus increasing the storage capacity by 15,000 acre-ft. without raising the crest of the dam. The Gibson shaft and tunnel are 29.5 ft. in diameter and have a capacity of 50,000 sec.ft.

Where the spillway cannot be placed on the dam and no natural site is available the side-channel spillway often is used, as at Don Pedro, Arrowrock, McKay and Tieton dams. This type of spillway often effects a saving in excavation and the spill is discharged well away from the dam.

* Report of a subcommittee of the hydraulic power committee—J. W. Jourdan, chairman. J. F. Davenport, C. deWitt, G. A. Hunt, C. M. Mardel, J. F. Partridge, G. M. Wills.

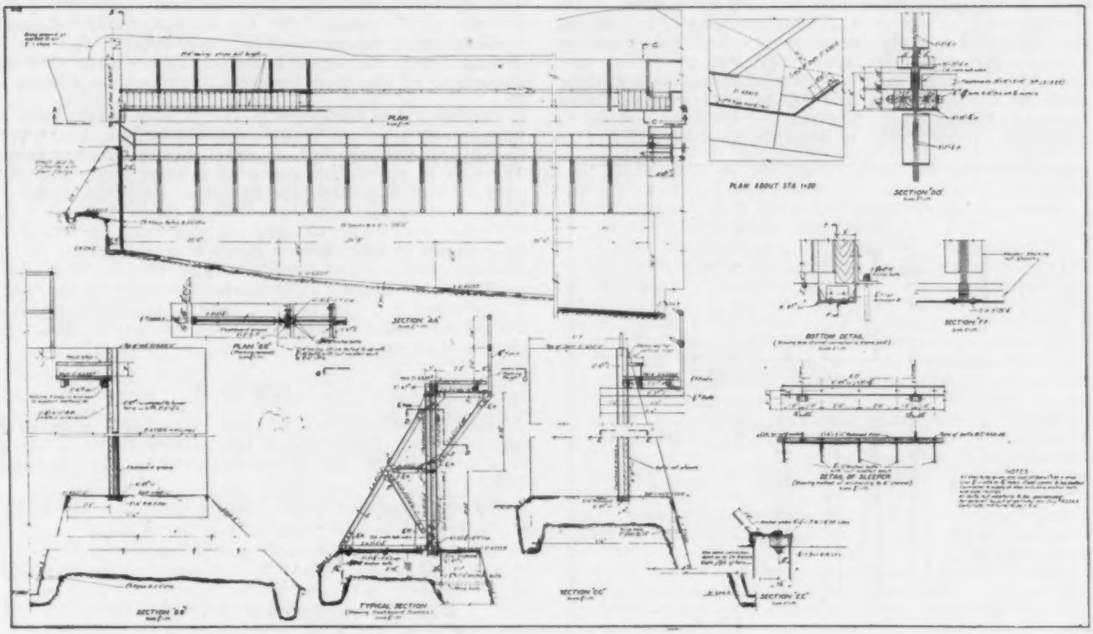

Fig. 1. Hand-adjusted flashboards.

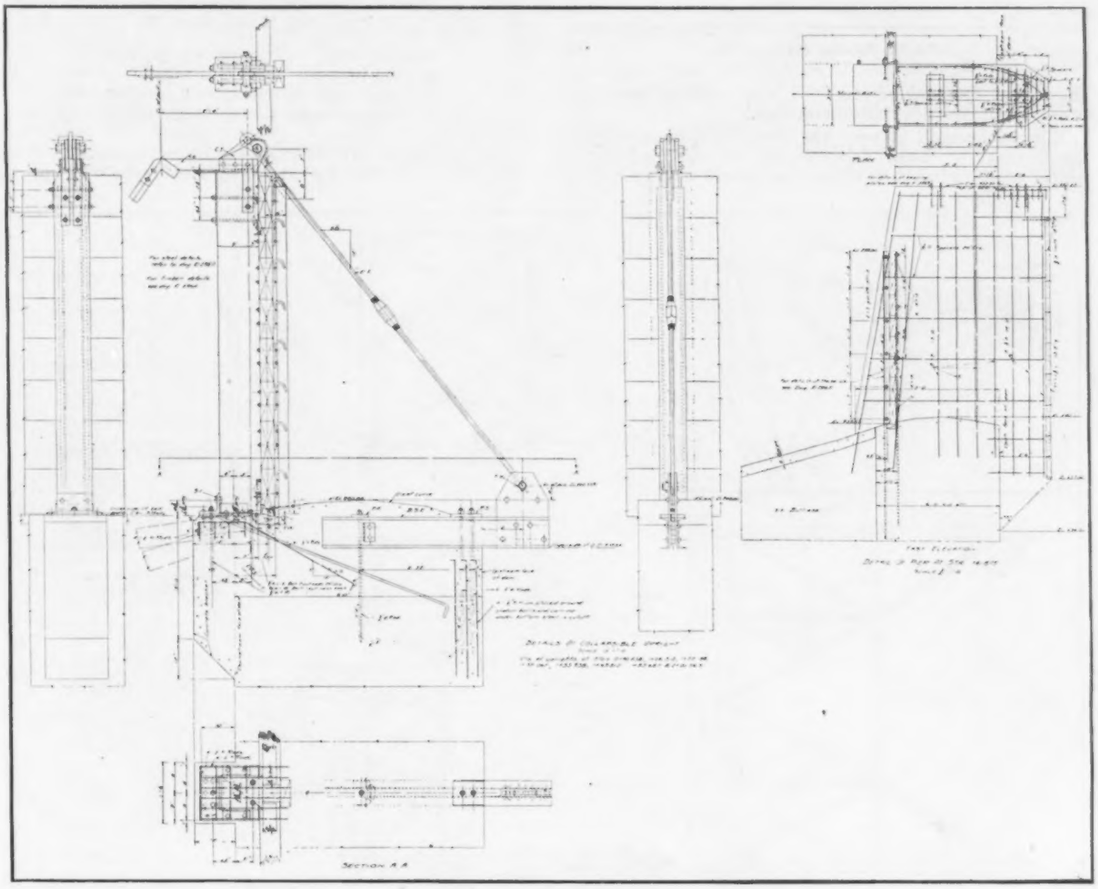

Fig. 2. Collapsible flashboards.

For diversion dams the problem of separating the spillway from the main dam becomes more difficult for the following reasons: (1) The dam usually is low and the topography of the surrounding country does not as a rule offer a suitable site. (2) The diversion dam usually is located lower down the stream, has a greater drainage area above it and has to pass greater floods than the storage dam. Therefore it becomes difficult to construct economically a separate spillway, owing to

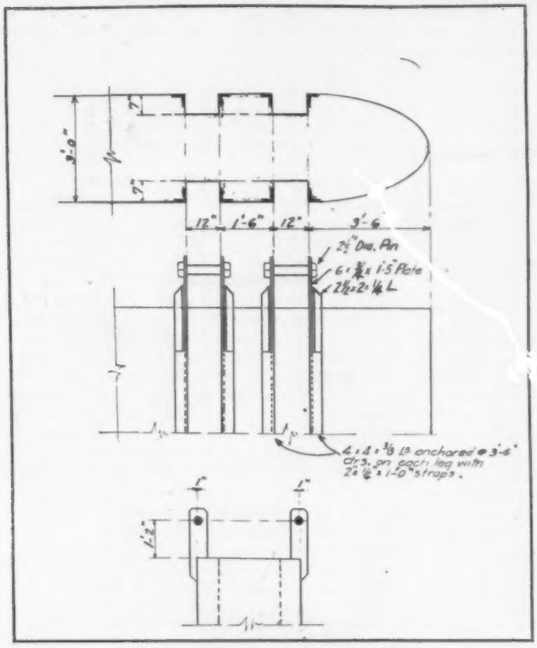

Fig. 3. Stop-log groove design.

the larger dimensions required, and recourse usually is made to an overpour diversion dam.

Where the spill is over the crest of a masonry dam the normal seasonal flood should be confined to the center of the structure where the excess energy may be dissipated by falling into a stilling basin. The stilling pool may be either natural or artificial. To obtain additional spill capacity for the exceptional flood, gate openings may be provided on each side of the center and used only during such floods. This will protect the abutments of the dam from continual seasonal wear.

Formulas and Coefficients—A spillway of the simplest type consists of an unobstructed overflow, the water rising and spilling over the crest as the flow increases. There is a great divergence of opinion regarding the coefficient of discharge for the usual spillway crest. It is the common opinion that 3.33 is too low a value for "C" for spillways of any appreciable deptth. As pointed out in Engineering News-Record, Vol. 99, No. 4, a large coefficient is found because the depth of flow over the weir usually is measured too close to the weir. If the head is measured far enough upstream so that the velocity head is negligible the formula for discharge can be expressed as:

$$Q = 3.087\ L\ H^{\frac{3}{2}}$$

The following information regarding discharge formulas and coefficients is taken from pages 5 and 6 of the report of the hydraulic power committee for 1924:

Horton Formula (Water Supply Paper No. 200 of the U. S. Geological Survey):

$$Q = C\ L\ H^{\frac{3}{2}}.$$

Where $C = [3.62 - 0.16\ (S - 1)]H^{\frac{1}{20}}$

Where S = slope of the crest curve rise (horizontal run over vertical rise).

For example,

If S = 2:1 and H = 4.0, $C = 3.46 \times 4^{\frac{1}{20}} = 3.74$

This formula is based upon experiments on relatively small dams.

W. F. Martin formula, deduced from stream gaging of U.S.G.S. Engineering News, Sept. 29, 1910, p. 321:

Merced dam	$Q = 2.491\ L\ H^{1.77}$
Austin dam	$Q = 3.196\ L\ H^{1.80}$
Yakima dam	$Q = 3.110\ L\ H^{1.65}$
La Grange dam	$Q = 3.088\ L\ H^{1.5}$

In his paper Mr. Martin has recomputed the formulas to show the variation in the value "C" in the

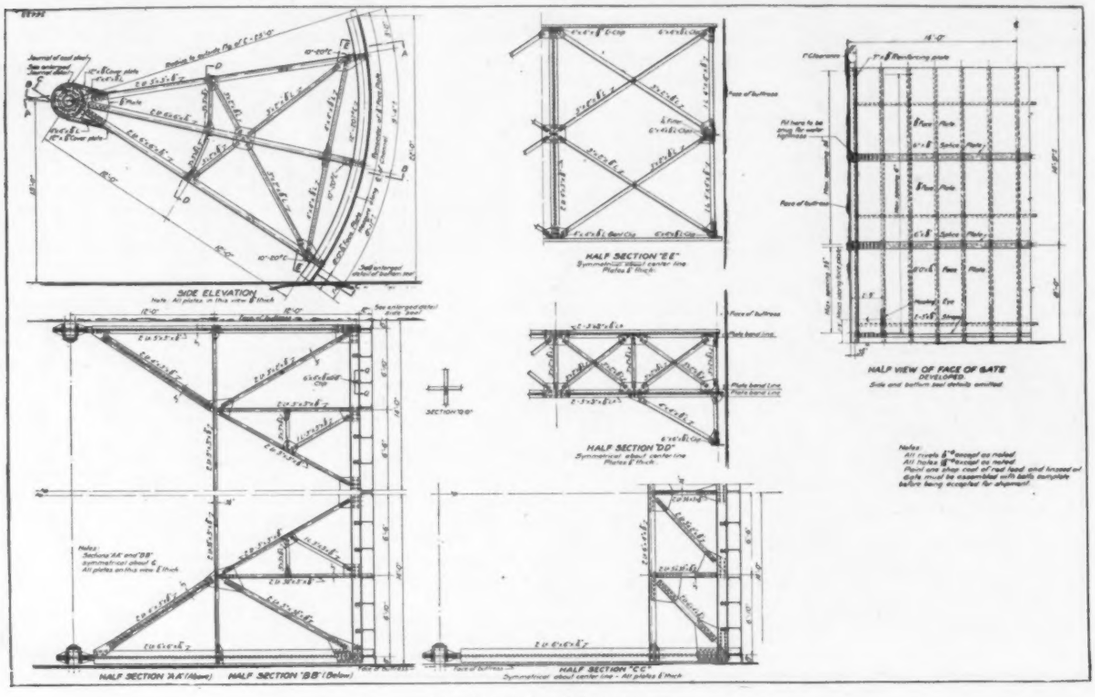

Fig. 4. Details of radial gates.

formula $Q = C\ L\ H^{\frac{3}{2}}$ with the results shown in Table I. With the exception of the La Grange dam, which is curved in plan, the coefficient increases as the head increases.

TABLE I—Values of "C".

Head	Merced Dam	LaGrange Dam	Austin Dam	Yakima Dam
0.5	2.065	3.088	3.003	2.803
1.0	2.491	3.088	3.196	3.110
1.5	2.780	3.088	3.315	3.305
2.0	3.003	3.088	3.402	3.451
2.5	3.190	3.088	3.473	3.568
3.0	3.352	3.088	3.524	3.668
4.0	3.623	3.088	3.620	3.829
5.0	3.849	3.088	3.694	3.960
6.0	4.041	3.088	3.754	4.071

In designing the spillway for the Grand Lake dam, Newfoundland, the formula: $Q = CH^{1.5}\ (1—0.05nH)$ was used to calculate discharge. The crest was favorable for flow and the piers were thin and pointed. The coefficient "C" varies from 3.30 to 3.90 with heads from 1 ft. to 10 ft. and "n" denotes the number of end contractions.

The effect of piers upon discharge, in the absence of actual experiments, probably is best estimated by considering that each pier causes end contraction thus more or less diminishing the effective length of the spillway crest, depending on whether the upstream nose of the pier is rounded or abrupt. The number of experiments has not been sufficient to determine closely the effect of piers upon the effective length of crest. W. P. Creager, in "Hydro-Electric Handbook," recommends a reduction of 0.04 H for each contraction for sharp-nosed piers and 0.1 H for thick, blunt piers.

Crest Regulation

Crest regulation is necessary where it is desired to keep the pond level as high as possible during periods of low or moderate stream flow (either to gain additional storage or additional head) and at the same time to allow flood flow to pass over the dam without raising the pond level to a dangerous height.

For cases where water is very valuable it is essential to adopt a type of control that is tight and will not waste the flow during periods of drought. For rivers containing much ice or a large amount of débris during floods the crest must be unobstructed or provided with piers that are sufficiently far apart to prevent stoppage. It is obvious that the need for close control is greater in low-head developments than in high-head plants because, for the latter, a few feet variation of head effects the output a relatively small amount. Devices that only partly control the fluctuations frequently are used since these are relatively less expensive.

Flashboards, Needles and Stop Logs—Flashboards usually are used only on storage reservoirs to conserve as much water as possible. They are put in place on the spillway crest to catch the very last of the excess runoff and at such time as the inflow to the reservoir about equals the draft therefrom.

Where the dams are of concrete and can stand a slight overtopping the spillway is flashed to the height of the dam. If the dam is of rock-fill a minimum freeboard of 3 ft. is allowed and if of earth 5 ft. is maintained. Gates for controlling spillways for rock-fill or earth-fill dams should be of positive action as the failure of the dam by overtopping would follow the failure of the gates to function. Where lake tenders are in constant attendance the feature of positive action is not of such importance providing it is possible manually or otherwise to open the gates under all circumstances. Many old rock-fill and earth dams in California are protected by flashboard spillways and have given years of continuous service. These spillways have been zealously watched during the run-off season and care is taken in placing the flashboards to be sure the end of the run-off peak has been reached. In some emergency cases it has been necessary to use dynamite to remove the flashboards quickly when an unexpected flood peak occurred or to remove débris which threatened to choke the narrow spillway openings. In that case it usually is impossible to replace the flashboards and the upper part of the reservoir storage is lost for that year.

A simple type of spillway where the flashboards are adjusted by hand is shown in Fig. 1. In this design the walkway is placed on the opposite side from the A-frame support. This arrangement permits the line of flashboards to be located closer to the spill lip than in the usual type. When the openings are partially flashed the sheet of overflowing water then will clear the spill crest. The flashboards rest against wooden shoulders fitted and bolted to the upright steel members of the frame. The flashboard openings are limited to 6 ft., the maximum size one man is considered capable of handling.

The spillway for the Crane Valley rock-fill dam of the San Joaquin Light & Power Corporation is a concrete

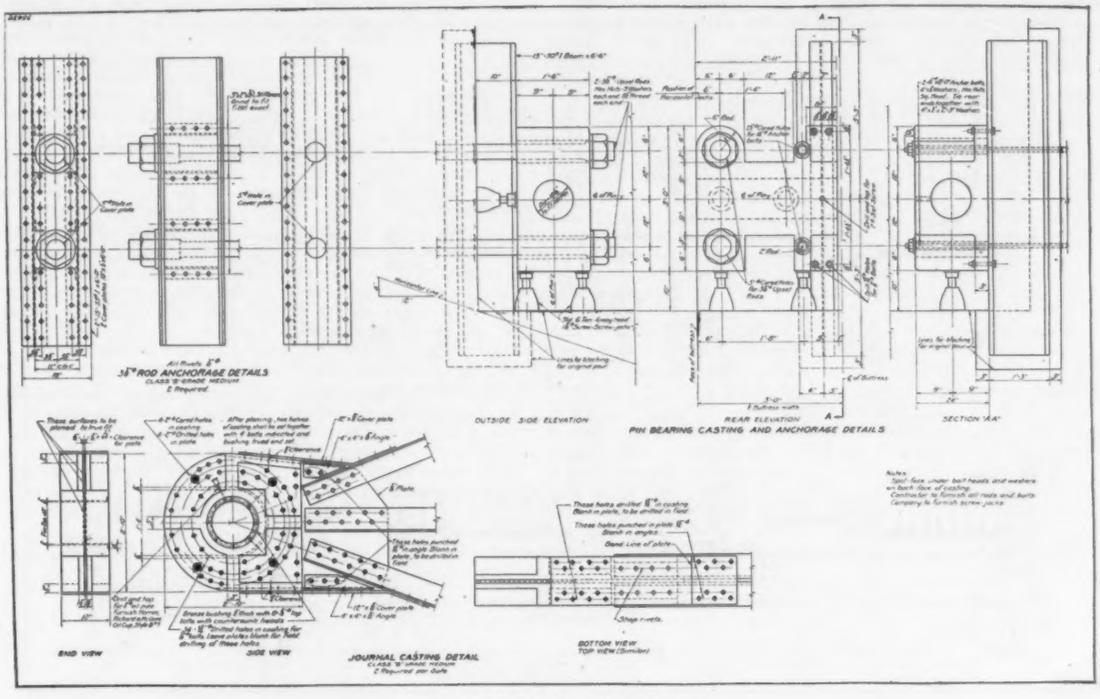

Fig. 5. Details of radial gates.

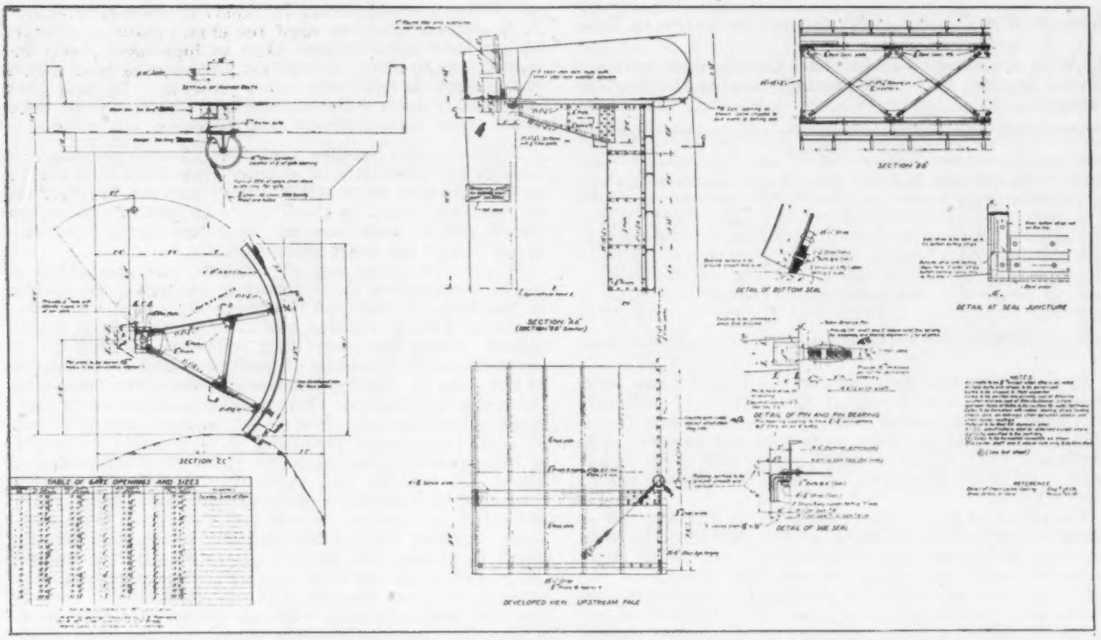

Fig. 6. A large radial gate.

structure consisting of four bays each 17.6 ft. long and separated by 2-ft. piers. The crest is controlled by means of horizontal flashboards consisting of 4 x 6-in. timbers laid flat. At the bottom there are three 6 x 12-in. timbers set edgewise. The flashboards are approximately 6.25 ft. long and are operated by hand by means of special steel lifting hooks in steel rail guides set in a vertical position. The top of the flashboard is 3.9 ft. below the top of the core-wall of the dam.

The forebay pond of the Kern Canyon plant of the same company is controlled by collapsible flashboards as shown in Fig. 2. Ordinary crest regulation is maintained by adding or removing flashboards by hand. This is accomplished by engaging hooks on the flashboards in an iron yoke fastened to a long handle. It is necessary to use a chain block supported from the steel truss spanning the dam for pulling the lower boards. In emergency, the device on top of the collapsible posts can be tripped thus allowing all the flashboards to go out. The boards and wooden posts are prevented from being washed away by chains which fasten them to the I-beam posts. When the emergency passes, the collapsible posts are erected again and the flashboards replaced.

The Big Bend diversion dam of the Great Western Power Company is provided with 10-ft. flashboards or needles to increase the pondage and head during the low-water season. The length of the arched crest is 330 ft. The 4-in. Oregon pine needles are beveled from 7¾ to 7⅞ in. in width to facilitate removal and are supported on timber frames bolted to angle iron curved to fit the ogee of the dam. The cost of the spillway control works was $24 per ft. of crest length.

In cold climates ice has caused serious trouble with needle flashboards. If ice is allowed to freeze to the needles the needles will be lifted over the sill when the pond level raises and the diversion will be lost tem-

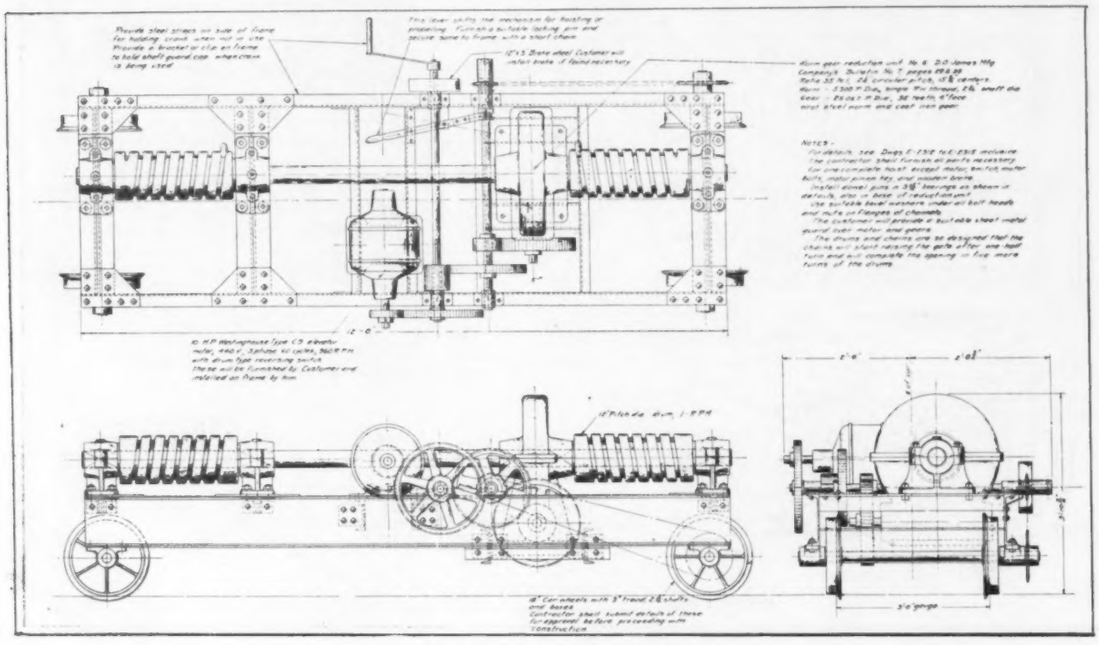

Fig. 7. A traveling electric gate hoist.

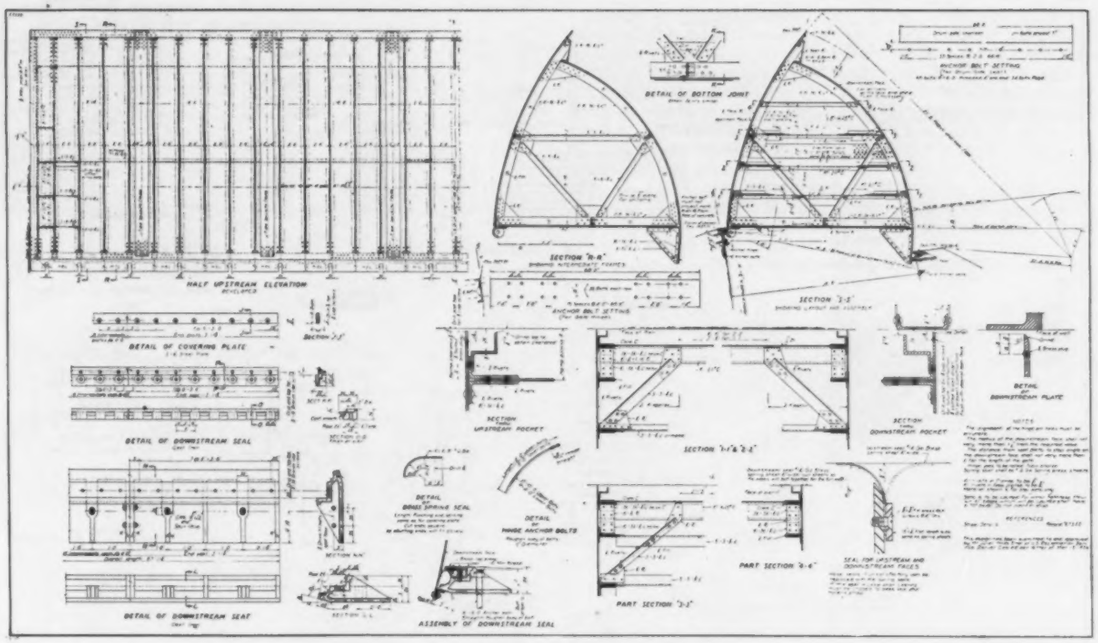

Fig. 8. Details of drum gates.

porarily. Operators are required constantly to prevent ice formation on the needles.

Stop-log grooves are provided sometimes to take care of unwatering to repair gates, etc. The standard construction of the Pacific Gas and Electric Company, including the device to facilitate jacking down the logs, is shown in Fig. 3. It may be noted that a double set of stop logs is used, it being intended to fill the space between them with dirt to make more nearly watertight. Some companies prefer slide gates for similar purposes due to the saving in time in case a unit is out of order, and again because the stop logs which may have been provided when the plant was constructed often are warped and sometimes even used for other purposes.

Slide Gates—Sliding lift gates seldom are used for crest regulation because of the large capacity of the hoist required to overcome the friction. Usually it is found more economical to use fewer piers and to adopt a large sized gate of a type easily lifted.

Radial Gates—Tainter gates perhaps are the type most commonly adopted for dams controlling medium sized drainage areas where floods are not excessive.

Regulation on the Kerckhoff dam of the San Joaquin Light & Power Corporation is accomplished by 14 radial gates 20 ft. wide by 14 ft. 4 in. high. The gates are operated by means of an electric hoist mounted on a traveling car.

Three radial gates 20 ft. wide by 11 ft. high are used in the bypass and at the intake to Pit River No. 1 plant of the Pacific Gas and Electric Company. These gates each has its own operating mechanism. Details of a battery of gates 28 ft. wide by 22 ft. high designed for Pit River No. 3 dam are shown in Figs. 4 and 5. The design was worked out carefully but the gates were not built, since it was decided to leave the dam ungated.

In general, radial gates for large hydro-electric developments must be designed for the particular use to which they will be put. Manufacturers' standard sizes may be obtained in stock from 4 ft. wide by 3 ft. high to 12 ft. wide by 7 ft. high. Where stock sizes and details are applicable some economies may be effected by their use instead of special designs.

Operating mechanisms vary from the individual hand-hoist for the smaller sizes to motor-operated hoisting cars where a series of large radial gates are installed side by side. In either case the gate is lifted by ordinary plough-steel cables, special flat plough-steel cables, or hoisting chains which wind on drums. Where very large chain is used it may be preferable to pass the chain over a toothed sheave and permit it to pile up on the floor. Two sources of power are desirable to insure continuity of supply. Auxiliary gas engines generally are considered undesirable. Ordinarily no mechanical effort is required to lower a radial gate, the weight being sufficient to overcome friction.

The introduction of a worm-gear in motor-operated lifting mechanisms is highly desirable to safeguard against a sudden power shut-down and dropping of the gate. Care should be taken, however, to avoid high-speed worm-gear reductions, much trouble has been experienced by heating of this type of drive with resulting binding and cutting.

Radial gates may be made practically water-tight if care is used in setting and adjusting the gate on its bearings and in selecting the type of side and bottom seals and in setting them. The usual side seal is a piece of rubber belting bolted to the upstream face of the gate and held against a rubbing surface on the side wall by the pressure of the water. Rubber side seals range from 6-in. wide 3-ply strips for heads up to 6 or 8 ft. to 7-in. wide 8-ply strips for heads up to 20 ft. The rubbing surface generally is a channel-beam curved to fit the face of the gate and flush with the side walls of the water channel. The bottom seal for gates with wood faces frequently is a wooden sleeper flush with the bottom of the channel and against which a special bearing block on the bottom of the gate sets.

Wood sills are likely to be bruised by ice or logs shooting under the gate as it is being opened. It is advisable, therefore, particularly in large installations to use an iron or steel sill. If a small amount of leakage is not a serious objection the steel knife edge at the bottom of the radial gate offers some advantages in the above respect. Such an installation entails considerable

TABLE II—Friction Co-efficient of 5-Ply Rubber Belting.

Load Lbs. Per sq. in.	NEW STRUCTURAL STEEL				RUSTY STRUCTURAL STEEL				CONCRETE			
	Dry		Wet		Dry		Wet		Dry		Wet	
	Start	Move	Start	Move	Start	Move	Start	Move	Start	Move	Start	Move
4	0.52	0.47	0.80	0.80	0.88	0.82	0.88	0.83	0.67	0.65	0.56	0.50
8	0.53	0.50	0.75	0.75	0.79	0.75	0.88	0.83	0.72	0.70	0.70	0.65
12	0.48	0.42	0.73	0.73	0.75	0.73	0.82	0.80	0.62	0.60	0.70	0.63

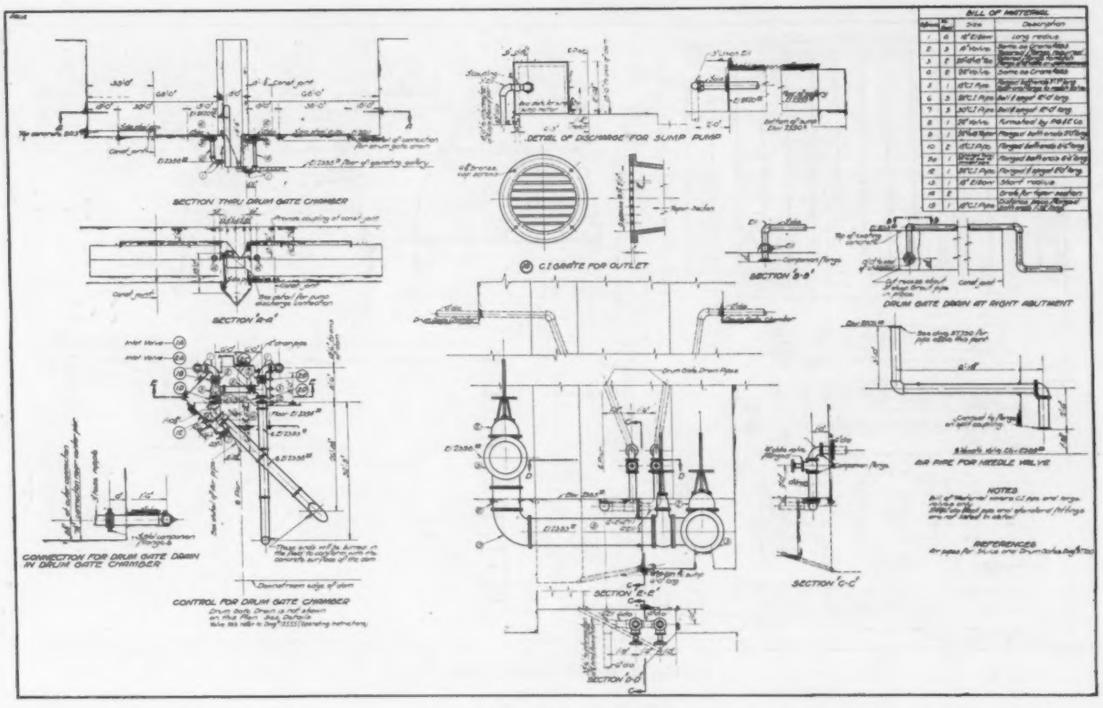

Fig. 9. Details of drum gates.

care and difficulty in setting. A more desirable type of bottom seal is a double layer of rubber belting parallel to the gate face and extending somewhat beyond it. These layers fold under the weight of the gate and usually press against a channel-iron seat which also is flush with the bottom surface of the channel. The layers vary from strips of 3-ply to 5-ply rubber 4 in. to 5 in. wide, depending upon the weight of the gate.

Results of tests to determine the coefficient of friction of rubber belting on structural steel and concrete are tabulated in Table II:

Results of the various trials were fairly consistent. On steel there is a decrease in the coefficient of friction as the load increases. When the surfaces are wet the friction is increased evidently due to the vacuum effect.

The largest and highest-head radial gates now in use on the Pacific Gas and Electric system and used for spillway regulation are installed on the Bullard's Bar dam. (See Fig. 6.) These gates were designed for an existing dam in which journal-box holes already were provided. A county roadway over the gate openings made the design difficult. Chain boxes were set in the concrete roadway in which the excess chain when the gates are lifted may be stored so that obstruction to traffic may be avoided. These gates were designed to give a maximum free opening when lifted and should permit logs and débris to pass without hitting the framework of the gate. Each gate journal boxing was made separate to permit the gates to be adjusted independently. The gates are motor-operated from a hand-drawn dolley car. Each gate weighs about 8,500 lb.

At the Kerckhoff dam of the San Joaquin Light & Power Corporation, the piers on the crest vary from 1 ft. 10½ in. to 3 ft. 9 in. thick. They are approximately 21 ft. high and are spanned by a reinforced concrete operating platform 8 ft. wide with an iron railing for protection. The rubbing surface for the side seals is a 6-in. channel-beam curved to fit the face of the gate and flush with the side walls of the water channel. Twelve-inch stop-log grooves are provided in the piers in front of the gates; these are used only in case of any emergency or if gate repairs become necessary.

The operating track is of 50-lb. rail imbedded in the concrete on a 36-in. gage. Slots 6 in. by 1 ft. 10 in. are provided in the platform through which two chains from each gate pass up to be engaged by the operating mechanism when it is desired to raise or lower the gates. The gates are operated by a traveling hoist (see Fig. 7) using electric power from an overhead trolley system for hoisting and traveling. The gates, which may be used at a maximum head of 14 ft., give very little trouble from leakage and are easily operated. Some little trouble was experienced at first by the chains breaking. This was eliminated by the use of heavier chains.

The face of the gate consists of ¼-in. plate bent on an 11-ft. radius. This plate is attached to curved 10-in. 25-lb. I-beams by means of 5-in., 6½-lb. channels, and 3 x 4 x ⅝-in. angle brackets. The radial members of the gate consist of 3½ x 3½ x 5/16-in. angles starred in pairs, trussed together and braced with angles and plates. The gage lines of the radial members intersect at the center of a 6-in. pin-hole in the bearing plate consisting of three 1-in. plates. Each pin passes through a pier and serves two gates. The gates are designed to withstand the normal pressure due to a possible maximum head of 19 ft. plus 25 per cent for impact. There are two radial trusses, like the one described, for each gate structure. The weight of each gate is approximately 14,500 lb.

Crest regulation at the Prospect dam of the California Oregon Power Company is accomplished by steel radial gates. The gates are operated through remote control from the power house. Hand control is provided for emergency use. In addition slide gates, or undersluices, are interlocked with the radial headgates, it being expected that the radial spillway gates need be operated only to care for flood discharge. Hoist chains are of extra-strength steel, but it is thought that an equalizer between lifting chains would work to advantage. There is a small roller at each upper corner of the gates to prevent binding during raising. The shaft of the hoisting drum is placed on an inclined plane to reduce the angle between the hoisting chain and the gate during the process of lifting. All motor-operated gates are provided with protective relays.

Tests have been made by the Pacific Gas and Electric Company to determine the lifting forces for radial gates. The results show that the forces varied from 88 per cent to 100 per cent of the total weight of the gates. In all cases the center of the axles are at the exact center of the line of thrust on the curved gate face.

An approximate formula for estimating weights of radial gates was given in Engineering News-Record, Vol. 96, No. 12, as follows: "Weight (lb.) = area (34 + 0.114 width × av. head)." The formula gives results approximately correct for small gates and about 10 per cent too high for large gates. See Table III for dimensions of radial spillway gates in service:

TABLE III—Radial Spillway Gates.

Company	Dimensions Height ft.	Dimensions Width ft.	Weight (each) lb.	Number of Gates	Year Installed
Calif. Oregon Power Co.	12.58	34	29,600	3	1927
Calif. Oregon Power Co.	11.75	11	12,300	2	1927
Calif. Oregon Power Co.	11	26	19,800	5	1925
San Joaquin Light & Power Corp.	14	20	14,500	14	1921
P. G. & E. Co.	10	20	8,500	19	1927

Sector or Drum Gates—The drum or sector gate has fulfilled the need for a crest gate which will give close spillway regulation by automatic or remote control and permits large unobstructed opening for the passage of flood flow. Sector gates have proved to be secure and easy to operate under the most adverse conditions and are not affected by ice or drift. This type of gate has been selected as the standard spillway gate by the U. S. Reclamation Bureau.

In general, drum gates are pivoted on a continuous casting anchored along one edge of the gate recess with

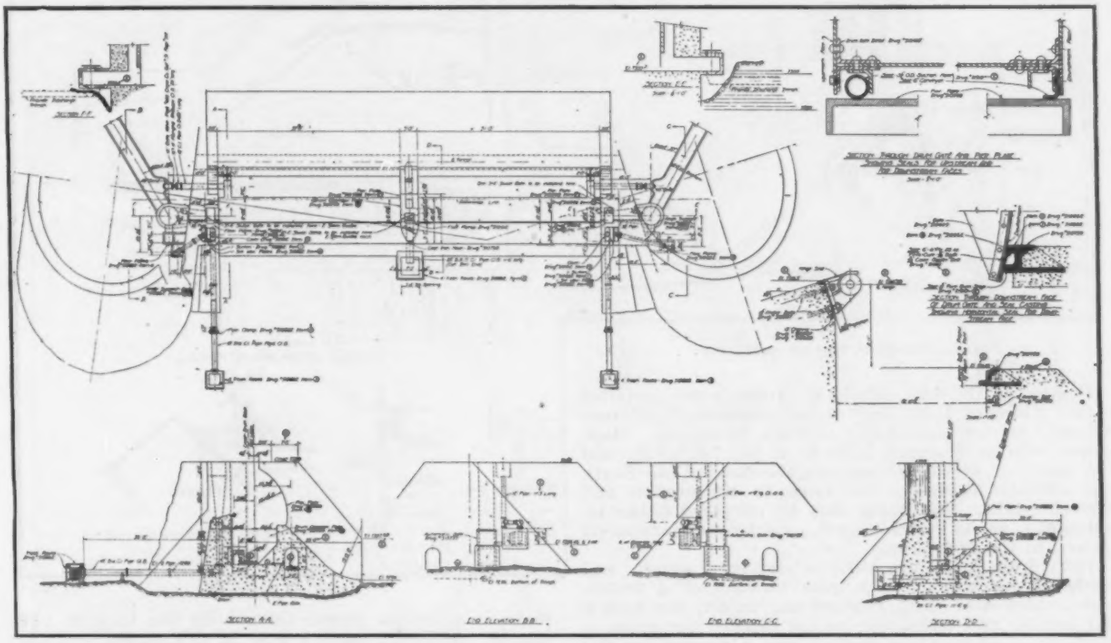

Fig. 10. Details of drum gates.

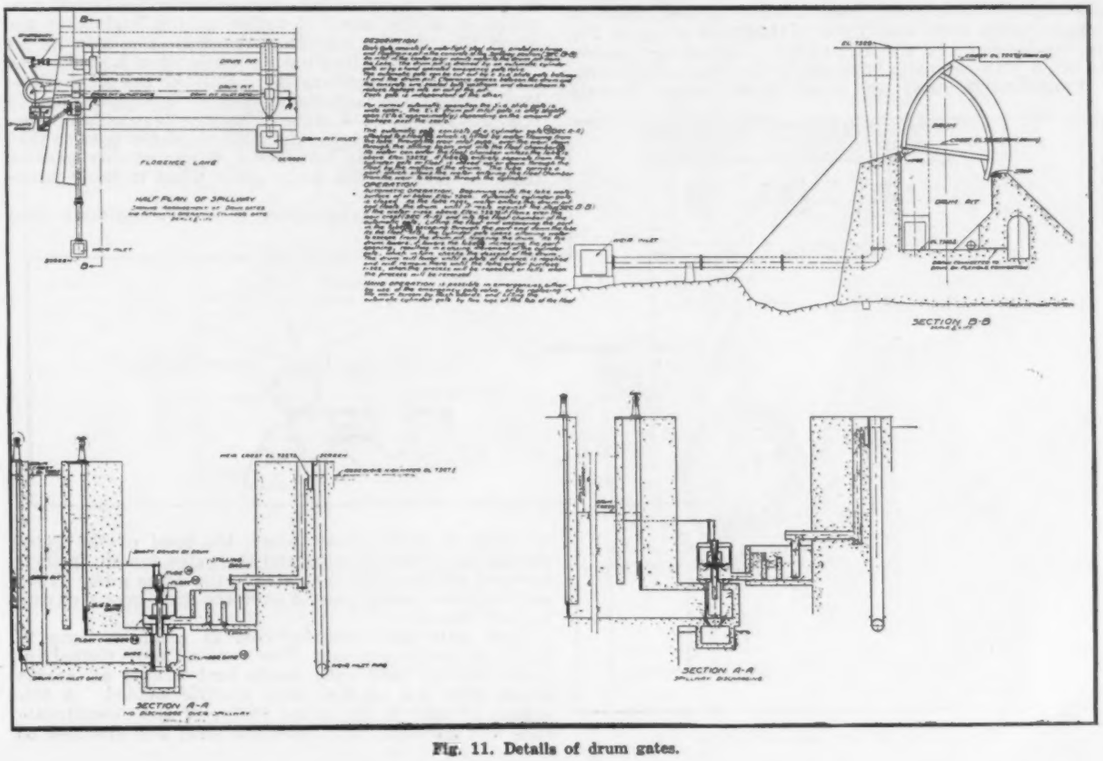

Fig. 11. Details of drum gates.

pin bearings at approximately 4-ft. centers. The gate is floated up by pressure from underneath and lowered by gravity upon relieving the pressure.

Details of the 14-ft. 6-in. x 68-ft. drum gates installed in the Pit River No. 4 dam of the Pacific Gas and Electric Company are shown in Figs. 8 and 9. Operation is not automatic although the movement of the gates may be remote controlled from the Pit No. 3 power house if desired. It was difficult to find a suitable spring brass for the downstream seal, but the seal material selected has given very little leakage in service. Each gate weighs 210,000 lb.

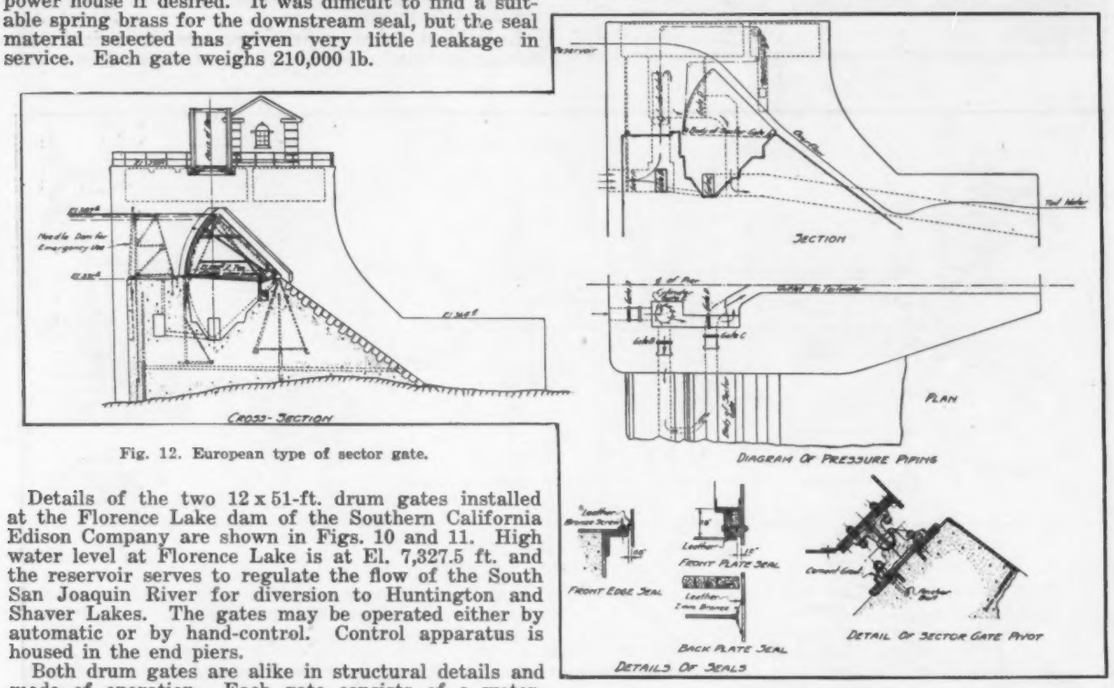

Fig. 12. European type of sector gate.

Details of the two 12 x 51-ft. drum gates installed at the Florence Lake dam of the Southern California Edison Company are shown in Figs. 10 and 11. High water level at Florence Lake is at El. 7,327.5 ft. and the reservoir serves to regulate the flow of the South San Joaquin River for diversion to Huntington and Shaver Lakes. The gates may be operated either by automatic or by hand-control. Control apparatus is housed in the end piers.

Both drum gates are alike in structural details and mode of operation. Each gate consists of a watertight, sheet-steel drum, caulked and welded and with a flat bottom and cylindrical sector faces. The drum is built up of ⅜-in. plate riveted over a ribwork on the three sides. A channel embedded in the concrete by anchor bolts runs along the upstream face of the spillway and forms the foundation for the hinge anchor castings for each gate. Each drum is pivoted upon 14 hinges which were built up to a thickness of about 2½ in. for bearings on the hinge pins. Each hinge anchor is fitted with eccentric bushings to facilitate alignment.

Considerable study was given to the design of seals because the accuracy of automatic control depends upon the amount of leakage past the seals from the pit. Three types of seals are used; spring brass, conveyor belting, and round suction hose. Spring brass is used at the upstream toe of the gate along the hinge casting. The seal at the downstream seat casting and at the downstream end of the side plates consists of 6-in. 8-ply conveyor belting. On the upstream end of each side plate is a hollow recess formed by the legs of two angles. A 3½-in. suction hose in this recess tends to flatten under the pressure of the water and acts as a seal.

The drum rests on the bottom of the pit until water in the lake rises sufficiently to enter the inlet pipe which is at the same elevation as the bottom of the drum pit. As the lake rises the drum floats in its pit until it reaches its limiting elevation when it strikes the stop on the gate seat casting. Further rise in the lake level brings the automatic control into operation to regulate the spill. A state of balance is maintained between the lake level and the position of the gate so that the elevation of the lake never is appreciably greater than the crest of the drum gates when in their maximum position.

No difficulty is encountered from ice conditions since the lake is drawn down below the level of the gates during the winter months and the gates remain in their lowered position with no water in the drum pits. Trash and logs are easily passed over the gate crests during run-off season.

Each gate was manufactured in seven sections to facilitate transportation. The sections were rivited together in the field with inside butt-straps; all seams which were not caulked were electric welded. A tolerance of only ⅛ in. in the radius of the downstream face was allowed. All structural steel was specified to

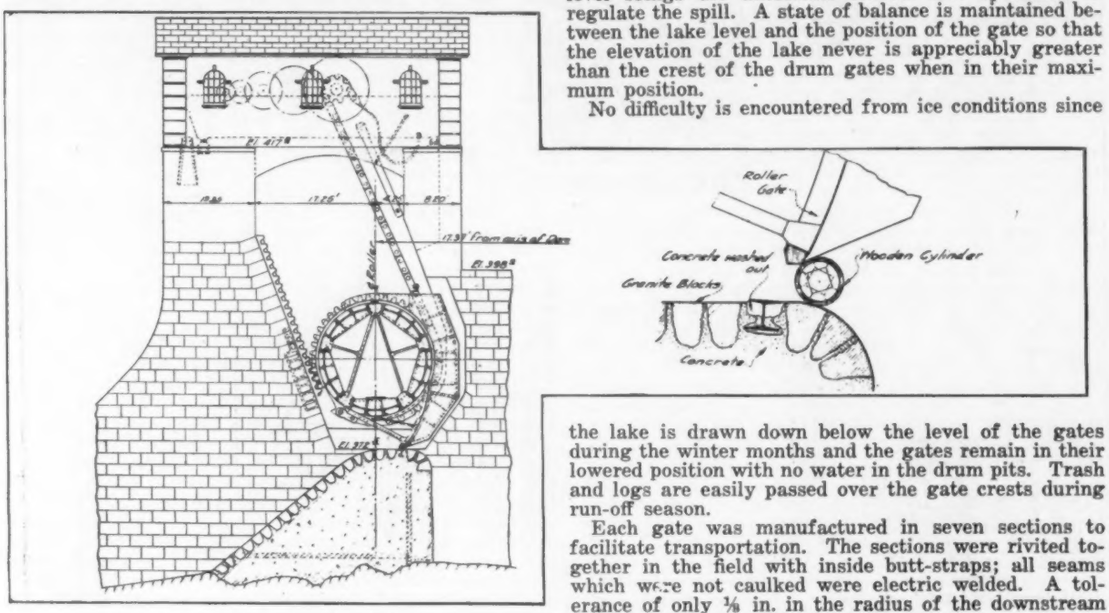

Fig. 14. A roller gate used in Norway.

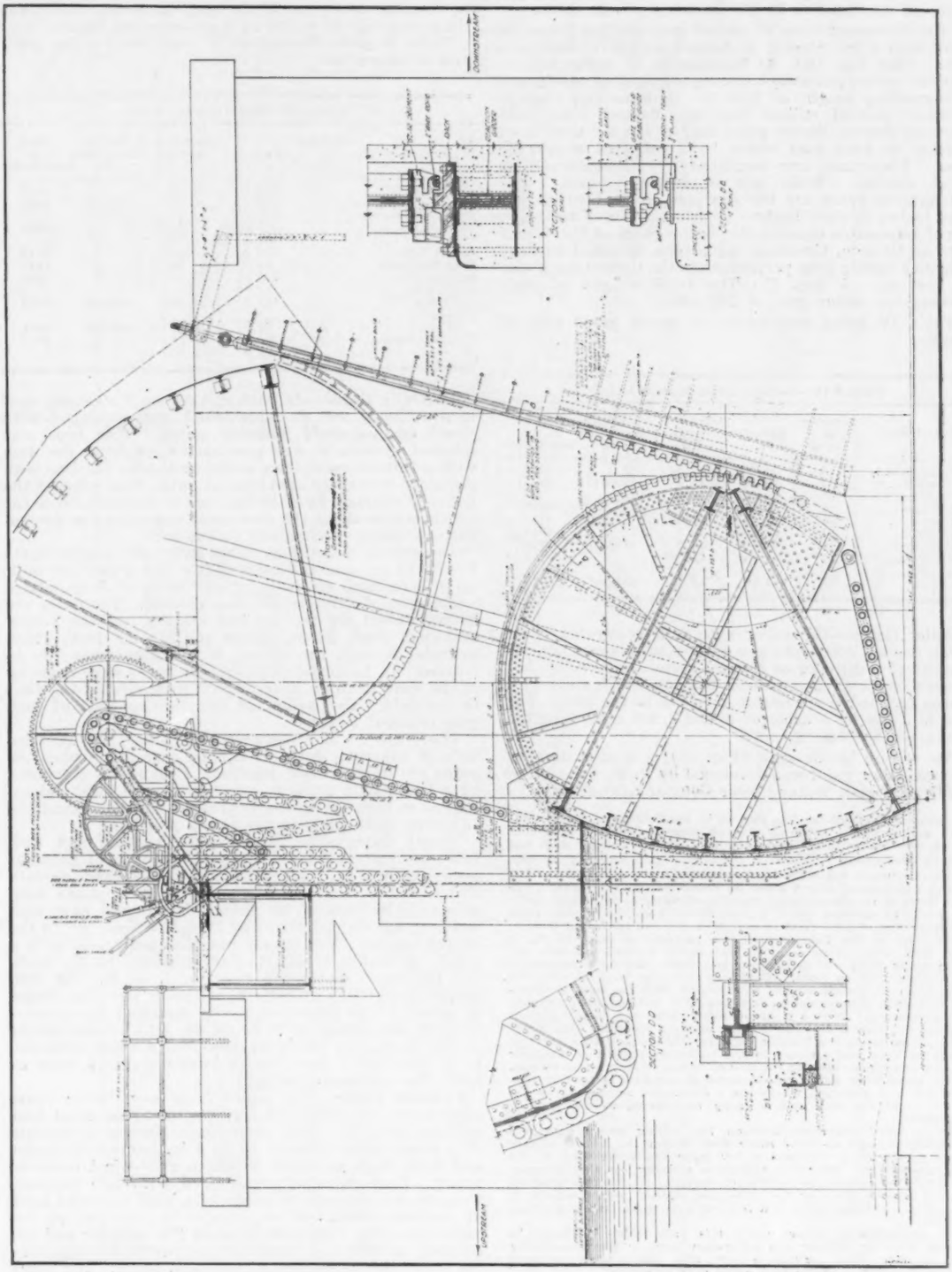

Fig. 13. A type of rolling sector gate.

conform with A.S.T.M. standards and steel castings to specifications A27-24, Class B, medium grade, of the A.S.T.M. Hinge pins and hinge anchor bushings were made of forged manganese bronze having a minimum elastic limit of 30,000 lb. per sq.in. Stresses in structural steel were not allowed to exceed 16,000 lb. per sq.in. in tension and 12,000 lb. per sq.in. in shear.

The European type of sector gate differs from the American type since it is hinged at the downstream side. (See Fig. 12.) At Raanaasfos in Norway there are two sector gates each having a length of 164 ft. and a regulating height of 12.3 ft. In a normal year in Norway several million logs are floated down each primary stream. Sector gates may be opened and closed quickly to pass logs which have collected above the dam. The gates are regulated by automatic or by hand control. Seals are of flexible brass. The Raanaasfos gates are not operated in winter, but are kept locked in their highest position. Winter operation is not impossible because the sector gates at the Weser dam at Bremen, Germany, have been operated without difficulty during long periods when the temperature was as low as —4 deg. F. The total weight of each Raanaasfos sector gate is 232 tons.

Table IV gives dimensions of sector gates now in service.

TABLE IV—Sector or Drum Spillway Gates.

Installation	Number of Gates	Length Ft.	Operating Height Ft.	Weight Each Gate Lbs.	Date of Installation
Florence Lake	2	51.00	12.0	.....	1927
Pit River No. 4	2	68.00	14.5	210,000	1927
Arrowrock	6	62.00	6.0	.....	1915
Tieton dam	6	65.00	8.0	.....	1925
Melones	9	57.16	10.0	82,360	1927
Don Pedro	10	57.00	8.5	.....	1923
Black Canyon	3	64.00	14.5	216,000	1924
Guernsey dam	2	64.00	14.5	.....	1927
Raanaasfos, Norway	2	164.00	12.3	464,000	1922

Roller Gates—The roller gate is a heavy-duty gate which has not come into general use in this country. It consists of a cylinder or trussed sector. The roller has at each end a circular geared bearing which rolls on a geared inclined track laid in a recess in the pier. The gate is lifted by a cable or linked chain encircling the gate near the bearing.

The rolling sector gate (Fig. 13), a modification of the true roller gate, was developed by V. H. Greisser of The Washington Water Power Company, who states:

> I consider the field for this gate to be for heights of water above 10 ft. and probably under 25 ft. with lengths from 50 to 100 ft. This is the range just beyond the field of the Tainter gate and probably overlaps in part that of the Stoney gate which is suitable for greater heads, but more limited spans.
>
> Each situation of course must be considered as a separate problem. Some of the factors are: quantity of water to be passed, available length of spillway, depth to foundation, and whether the water level may vary at peak flood as compared with an operating level.
>
> The limit of the Tainter gate size probably is near 12 ft. in depth with 30-ft. span and for that depth requires an ogee sill so the water sheet will drop down and make possible a reasonable radius from face to pivot. If the downstream level is comparatively near the upstream level at times of flood the need of clearance will make it necessary to raise the pivot and supporting girder, or other member. With a relatively short radius the load of gate at the piers will have a direction sloping decidely upward. This is one of the objections to the Tainter gate, as this reaction then must be carried by rods and anchors to the upstream portion of the pier masonry or requires making the pier of excessive length and volume.
>
> With the rolling sector gate the load of the gate is applied relatively low in a direction which has a downward slope fixed by the inclination of the seat and is easily transferred to the base or foundation.
>
> The principal difference between the rolling sector gate and the earlier German so-called roller dam is that the former utilizes trusses as the main members which carry the water load to the ends, whereas the latter has utilized a cylinder for this purpose. Of course, the relative disposition of material in the two types of members is such that for the same load carried more material is required in a cylinder than in a truss and the cross-frames between the trusses.
>
> The commendable feature about this gate which it shares in common with the Tainter and roller-dam types is the accessibility of the structure when the gate is open; also, that a relatively large quantity of water is passed with small gate movement.

At the Lewiston, Idaho, development of the Inland Power & Light Company three roller gates were installed for the control of all ordinary floods. Each gate is 105 ft. long and 18.5 ft. deep. Each consists of 17 cylinders fastened by field-riveted, milled, butt-strap joints. A hoist mechanism operates a link chain on the driven end of the gate.

The roller type of spillway gate is used in Norway for winter regulation as well as during the flood season. (Fig. 14.) Electric heating elements installed in a recess back of the end plates keep the gate ready for operation under the most adverse conditions. Logs are not passed under the roller gates. Normal operation is by electric motor, but if the electric energy should fail the gates may be raised by hand-operated hoists.

Table V gives dimensions of noteworthy roller gates now in operation:

TABLE V—Roller Spillway Gates.

Installation	Number of Gates	Length Ft.	Operating Height Ft.	Weight Each Gate Lbs.	Date of Installation
Lewiston	3	105.0	18.50	.....	1927
Spokane (sector)	2	60.0	20.00	156,400	1921
Post Falls (sector)	1	100.0	12.50	175,100	.....
Hood River	2	25.0 75.0	7.67 6.25	.....	1924
Grand Valley	6	70.0	10.25	.....	1915
Wallenpaupack	2	67.5	14.00	.....	1925
Bellows Falls	2	115.0	18.00	.....	1928
Raanaasfos, Norway	1	147.5	21.30	546,000	1922
Solbergfos, Norway	3	98.5	28.70	298,000	1924
Vamma, Norway	2	65.6 91.9	8.20 11.50	.....	1915

Butterfly Gates—At each end of the Exchequer dam is a spillway 168 ft. wide which was equipped with seven vertical-shaft butterfly gates. This type was selected because it was possible to construct the dam with a thinner crest than would have been feasible with the more commonly used type of gate. Operation of the gates is effected by a 20-hp. motor mounted on a car which moves along the dam crest engaging the several gate-operating mechanisms successively.

The outside dimensions of the gates are: length 24 ft., height 14 ft., and thickness 3 ft. The gates are built up of structural steel consisting chiefly of ⅜-in. plates and angles of suitable size and spacing. The gates are hollow except for the internal bracing and the hollow cast-steel shaft, 24 in. square and 2¼ in. thick, which extends through the center of the gate from top to bottom. To facilitate shipment the gates were made up in the shop in three pieces which were riveted together in the field. The weight of the rotating part of each gate is about 19 tons.

There are no piers between the gates. The rounded ends of adjoining gates fit against each other when the gates are in the closed position. Leakage is prevented by a brass strip fitted to one end of each gate and arranged so that the spring is pressed tightly against the adjoining gate when in the closed position.

Stoney Gates—The Stoney gate has not met with favor in Western United States. This type of gate has been extensively used in the southern and eastern states and in Canada where it has been much used primarily because of its simple design and ease with which it can be operated and kept free from ice in the winter season. The Stoney gate has been used with a depth of water of 50 ft. for openings 50 ft. wide, and for lesser depths for width up to 80 ft. The gate moves in vertical grooves in masonry piers on trains of rollers. The gates are partly operated by counterweights amounting to 75 or 80 per cent of the weight of the gates, and partly by powerful gearing arranged to be worked by hand or by power serve to raise or lower the unbalanced weight.

Cylinder Gates—(No report from any Pacific Coast company.) The Elephant Butte spillway contains four cylinder gates for flood regulation. Each gate consists of a boiler-plate cylinder 10 ft. 4 in. internal diameter and 8 ft. high mounted within a cylindrical concrete tower. Each cylinder is provided with two counterweights and is raised by means of a hand-operated hoist at roadway level. A single seat is provided at the bottom and the clearance between the cylinder and the concrete is kept at a minimum to prevent leakage over the top of the cylinder in case of high water. The lower seat ring is an iron casting set in the concrete and carries three castiron posts which help to support the concrete tower. Each gate discharges through a curved concrete draft tube leading under the spillway weir.

Siphon Spillways—The siphon spillway is a device for discharging water over a dam. It utilizes the available head to produce a higher velocity of flow than would be attained at an overflow weir, thus increasing the dis-

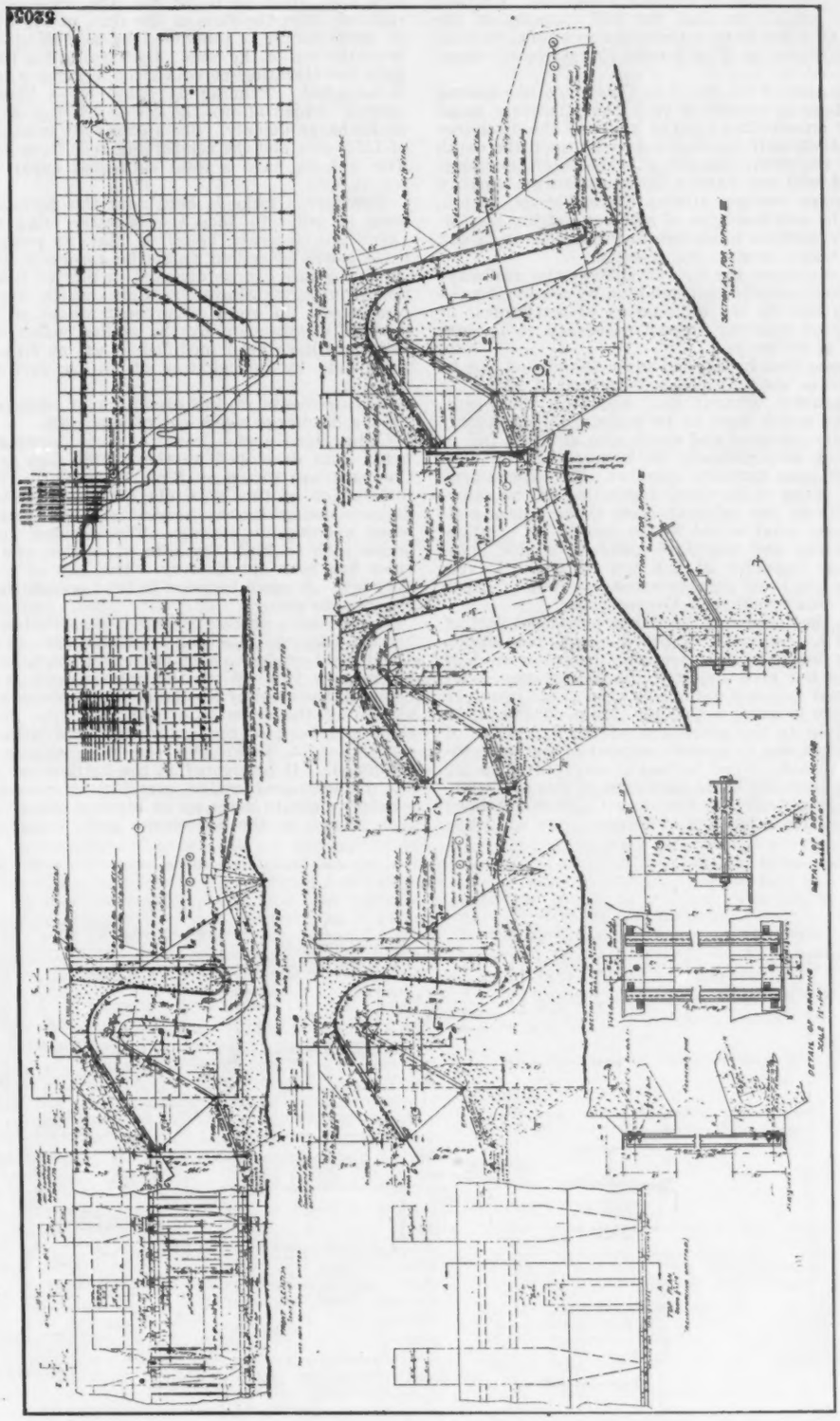

Fig. 15. Siphon spillways.

charge. The siphon spillway has many advantages over any other type of spillway control apparatus up to a required capacity of about 200 sec.-ft. per ft. of crest.

The evident advantages of this type of spillway are as follows: The action is entirely automatic. Priming takes place quickly so that the full capacity of the spillway is effective in an extremely short time, varying from 5 or 10 sec. to 2 or 3 min. for extremely large siphons.

The fluctuation of the water surface above the normal reservoir stage is restricted to a comparatively small range. For an overflow type of spillway the discharge over the dam or weir depends primarily upon the depth of water on the crest, increasing as the depth increases. Therefore it will not have a large discharge capacity until the water surface attains a considerable depth. Neither is the overflow type of spillway quickly responsive to the variations in stream flow nor does it closely control the water level in the reservoir.

In many instances the use of siphon-type spillways would reduce the cost of construction by conserving the crest length and by the elimination of mechanical or other forms of external energy necessary to operate other types of spillways.

It is believed that in a broad sense the siphon can be characterized as the only absolute method of obtaining adequate capacity without the supplying of several moving parts which have to be maintained constantly and frequently replaced and which also at times fail to operate either automatically or because of the non-attendance of some intended operator. The siphon type of spillway, owing to its closer regulating of the reservoir level, allows the spillway crest to be raised considerably above what would be the case in an overflow type of spillway and therefore makes available additional storage capacity at the top of the reservoir where the water is of greater value per unit of depth than at any other portion of the reservoir.

Under the limitations of discharge per lineal foot of crest length of spillway, as noted above, the siphon spillway can be built approximately in from one-half to two-thirds the area required for almost any other known automatic or non-automatic type of spillway. In locations where freezing conditions obtain, consideration should be given to the possibility of the formation of ice in the siphon due to a small amount of water washing over the throat. Some method of controlling the air in the siphon probably could take care of this condition.

At Huntington Lake the Southern California Edison Company provided a battery of seven siphon spillways (Fig. 15) which would prime at different elevations of the lake surface over the normal operating level. The siphons are similar in construction, but the throat crests are at slightly different elevations and the downstream legs vary from 15 to 22 ft. The air-control passage running from the face of the dam to the upper throat of each siphon is controlled by a slide gate operated from the top of the dam. By varying the height of the gate the elevation at which the siphons prime thereby is adjusted. Priming is aided by a "back-pressure control" which allows the air in the top of the siphon to discharge quickly. The siphons are made of concrete of 1:2:4 mix and the reinforcing rods have hooked ends. The siphons have a total estimated capacity of 5,500 sec.-ft.

Huntington Lake is kept near the normal operating level in order to keep the effective head on the Big Creek No. 1 power house as high as possible. Very little water is spilled from the reservoir because any surplus water can be diverted to Shaver Lake through the Huntington-Shaver conduit, which recently was completed. In order to prevent waste of water and damage downstream by the spilled water, the siphon spillways have been modified to act as free-flow spillways only by the addition of an air duct to prevent priming.

Measurements of the discharge of siphon spillways show a discharge coefficient of about 0.6.

Collapsible Gates—Details of a counterweighted automatic gate developed by the Pacific Gas and Electric Company are shown on Figs. 16 and 17. The original installation of this gate did not prove entirely satisfactory owing to the excessive momentum acquired when opening or closing. The dashpot control was added then to limit the rate of motion ond operation since has been satisfactory. The cost of this gate is very low. A small increase in head is sufficient to cause the gate to drop.

The Stickney automatic gate is described in Creager's "Hydro-Electric Handbook." This consists of two leaves set at right-angles to each other and hinged at the point where they join. When the gate is down it rests in a recess in the crest of the dam. The operation is similar to that of the drum gate. Another type described in the same book is the automatic gate with a rolling counterweight, as installed for the Tallulah Falls development. It is pivoted at the bottom and as it tilts due to increased water pressure it causes a roller counterweight to move up an inclined plane. A similar type known as the Stauwerke gate, using a walking

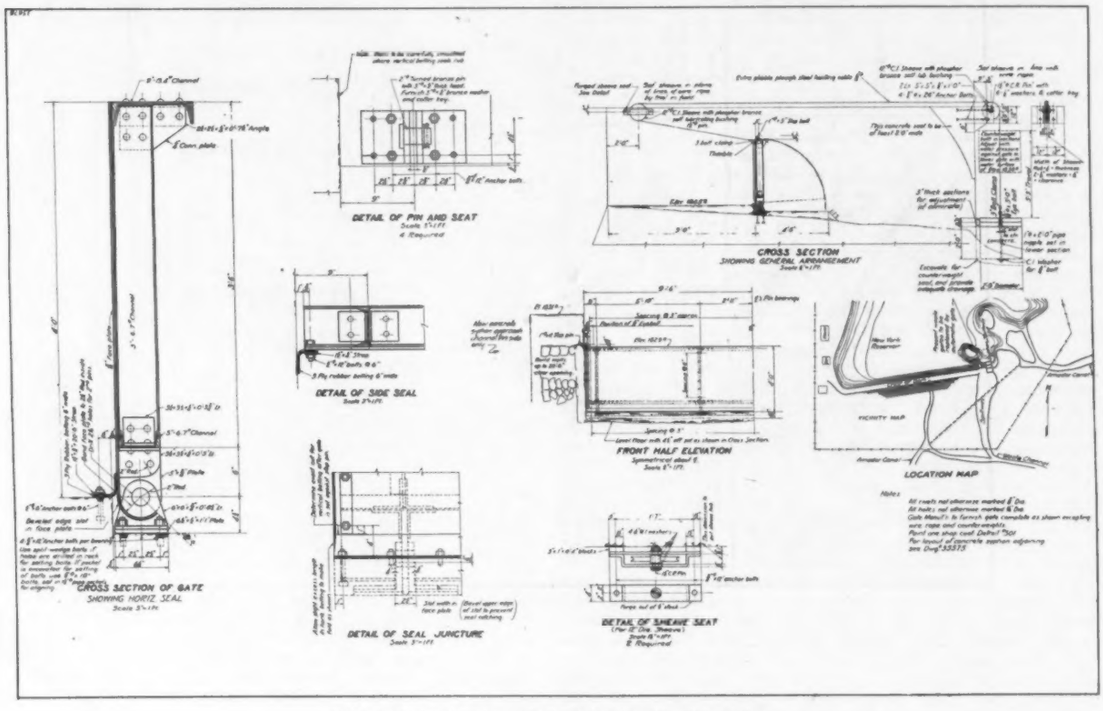

Fig. 16. Details of counterweighted automatic gates.

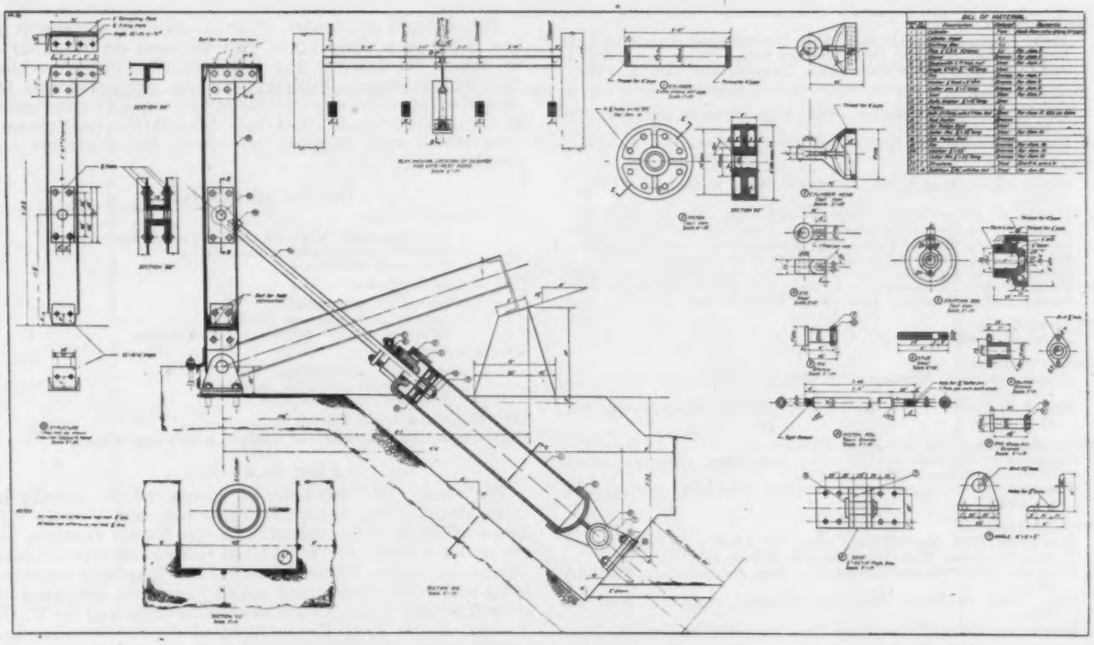

Fig. 17. Details of counterweighted automatic gates.

beam and counterweight, was installed on the Cedar River, Nashua, Iowa. The gates are 7 ft. high by 46 ft. long.

Automatic Gates—Automatic-control gates of California manufacture have been used widely. The gate is counterweighted and actuated by a float which may be governed by either the upstream or downstream water level.

The Pacific Gas and Electric Company has three of these gates installed, two 6 x 12 ft. for constant level above the gate and one 4 x 6 ft. for constant level below the gate. None of these installations is made with flashboard openings, there being only the one opening for the gate. These gates with one exception have operated successfully. The fault in the one case of unsuccessful operation was in the setting of the pin bearing and since that has been remedied there has been no trouble. In addition, better results have been obtained with a rubber seal which crimps through an angle of 90 deg. and rubs on the side walls rather than by providing a notch in the walls which permits the rubber belting to lie flat and parallel to the face of the gate.

General Conclusions

In design the amount of overtopping to consider will vary with the number of openings and the percentage of gates which are assumed to be nonoperative in relation to the total number when passing the maximum flood. In any case the stresses produced under maximum overtopping conditions should not be great enough to produce permanent deformation. In general the spillway should be designed for a maximum crest which should not be exceeded. Overtopping might cause far more damage than to the gates themselves.

The materials of construction and stresses to be used for various types of spillway gates should not differ materially from other types of metal structures. The American Institute of Steel Construction specifications well may apply to gates made of structural steel. Gates of cast iron should not have tensional stresses greater than 2,000 lb. per sq.in., and compression greater than 12,000 lb. per sq.in. Cast steel stresses (Class B, Medium) should not exceed 14,000 lb. per sq.in. in either tension or compression; semi-steel when made with 25 per cent of steel scrap may have tensional stresses up to 3,000 lb. per sq.in., and compression up to 12,000 lb. per sq.in. Steel forgings should permit stresses equal to those used for structural steel.

Wearing parts of most types of gates should be made of non-corrosive metal such as bronze or babbitt and so designed that replacement may be made readily. The bearings of radial-gate journals usually are of steel, however, as the leverage of lift is so great that a greatly increased friction in the journals will not increase the lifting load materially.

The desirable speed of operation of most types of spillway gates ranges from 2 to 4 ft. per min. Greater speeds than these are not necessary and require heavier operating mechanism. Where gates have rubber seals faster speeds may result in excessive wear or possible binding. Norwegian practice has been based on a rate of opening of about 3 min. for the sector gates, 12 to 14 ft. high, and approximately 30 min. for the larger roller gates.

The maintenance required by spillway gates normally is very inexpensive. Painting of gates in the original installation should be thoroughly investigated and some durable coating such as asphaltic enamels selected. The expense of maintenance painting then will be reduced to a very nominal amount. The journals and operating mechanisms should be greased periodically and tested by partially raising and lowering the gates. This will insure that the gates are operative and break films of corrosion which may be forming.

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Flumes*

The subcommittee on flumes in the work of the hydraulic power committee for 1927-1928 had its subject divided into seven subheadings with an assignment of a subheading to each member of the subcommittee. The report will retain this subdivision and a chapter is assigned to each subheading.

* Report of subcommittee of hydraulic power committee—C. B. Carlson, chairman. G. H. Bragg, Walter Dreyer, R. D. Likely, A. C. Norton, J. F. Partridge, O. J. Schieber, G. M. Wills.

The subject of flumes offers a wide range and it is the hope that this report can be used at least as a reference for present-day methods of design, erection and maintenance. Information and examples are included of installations outside of the member companies of the Pacific Coast Electrical Association to illustrate uses which may suggest references for problems encountered.

Outline of Subjects

I. Flow in Flumes
Recommended values of N in Kutter formula.
Critical velocity and critical depth.
Freeboard allowance.

II. Inlets to Flumes
Hydraulic calculations.
Length and shape of inlet.
Effect of critical velocity on inlet design.

III. Flume Outlets
Hydraulic calculations.
Length and shape of outlets.
Effect of critical velocity.

IV. Short and Long Flumes

V. Typical Calculations for Replacing Existing Flumes

Flow in Flumes

The steady-flow capacity of open conduits usually is calculated by the familiar Chezy formula $V = C\times RS$. The coefficient C is evaluated in the Kutter formula by assuming a value of "n" for the particular type of surface to be used. These formulae are long and cumbersome and many charts and tables have been prepared to simplify their use. Two such charts prepared by F. C. Scobey of the U. S. Department of Agriculture are included herewith and should be found valuable in the solution of the Kutter-Chezy formula for flow in flumes, the range in value of "n" being from 0.010 to 0.016. Figure 2 covers slopes ranging from 0.001 to 0.005 and Fig. 3 includes slopes between 0.005 and 0.3, being of particular value in the calculation of flow in chute drops or rapid flumes. Figure 3 is a chart prepared by the U. S. Reclamation Service for flow in metal flumes based on "n" = 0.012 and freeboards in accordance with their standards. Table II and III give carrying capacities of metal flumes for value "n" = 0.012 and 0.013 with freeboard equal to 0.06 diameter. Table I and

No.	Diameter		Area		Hydraulic Radius		6% Dia.	Top Width	Critical Velocity
	Inches	Feet	Full	6% F. B.	Full	6% F. B.			
12	7.64	.637	.1593	.1350	.1593	.1462	.46	.632	2.52
15	9.55	.796	.2487	.2108	.1989	.1826	.57	.790	2.93
18	11.46	.948	.3581	.3035	.2387	.2191	.69	.941	3.22
21	13.37	1.114	.4870	.4128	.2785	.2557	.80	1.106	3.45
24	15.28	1.273	.6366	.5396	.3183	.2922	.92	1.264	3.71
30	19.10	1.592	.9947	.8431	.3980	.3654	1.15	1.580	4.15
36	22.92	1.910	1.432	1.214	.4775	.4383	1.38	1.896	4.54
42	26.74	2.228	1.950	1.653	.5570	.5113	1.60	2.212	4.91
48	30.56	2.546	2.546	2.158	.6365	.5843	1.83	2.527	5.25
60	38.20	3.183	3.979	3.373	.7958	.7305	2.29	3.160	5.87
72	45.84	3.820	5.730	4.857	.9550	.8767	2.75	3.792	6.42
84	53.48	4.456	7.799	6.610	1.114	1.023	3.21	4.424	6.94
96	61.12	5.093	10.186	8.634	1.273	1.169	3.67	5.056	7.42
108	68.75	5.730	12.892	10.926	1.433	1.315	4.13	5.689	7.87
120	76.39	6.366	15.916	13.490	1.592	1.461	4.58	6.330	8.29
132	84.03	7.003	19.257	16.322	1.751	1.607	5.04	6.953	8.69
144	91.76	7.639	22.918	19.425	1.910	1.753	5.51	7.584	9.06
156	99.31	8.276	26.897	22.798	2.069	1.899	5.96	8.216	9.46
168	106.95	8.913	31.195	26.441	2.228	2.045	6.42	8.849	9.81
180	114.59	9.549	35.810	30.353	2.387	2.191	6.88	9.480	10.15
192	122.23	10.19	40.744	34.535	2.548	2.339	7.33	10.12	10.48
204	129.87	10.82	45.996	38.986	2.705	2.483	7.79	10.74	10.80
216	137.51	11.46	51.566	43.707	2.865	2.630	8.25	11.36	11.11
228	145.15	12.10	57.454	48.698	3.025	2.777	8.71	12.01	11.42
240	152.79	12.73	63.662	53.960	3.183	2.922	9.17	12.64	11.72
252	160.43	13.37	70.187	59.490	3.343	3.069	9.63	13.27	12.01
264	168.07	14.01	77.030	65.291	3.503	3.216	10.08	13.91	12.28
276	175.71	14.64	84.194	71.363	3.660	3.360	10.54	14.53	12.57
288	183.35	15.28	91.673	77.702	3.820	3.507	11.00	15.17	12.84
300	190.99	15.92	99.472	84.312	3.980	3.654	11.46	15.81	13.10
312	198.62	16.55	107.588	91.192	4.138	3.799	11.92	16.43	13.36
324	206.27	17.19	116.027	98.344	4.298	3.946	12.38	17.07	13.61
336	213.91	17.83	124.779	105.763	4.458	4.092	12.83	17.70	13.87
348	221.55	18.46	133.851	113.451	4.615	4.237	13.29	18.33	14.12
360	229.18	19.10	143.239	121.409	4.775	4.383	13.75	18.96	14.36
372	236.82	19.74	152.946	129.637	4.933	4.528	14.21	19.60	14.59
384	244.46	20.37	162.974	138.137	5.093	4.675	14.67	20.22	14.83
396	252.11	21.01	173.324	146.909	5.253	4.822	15.13	20.86	15.06
408	259.74	21.65	183.983	155.944	5.413	4.969	15.58	21.49	15.29

Table I—Data for calculation of freeboard.

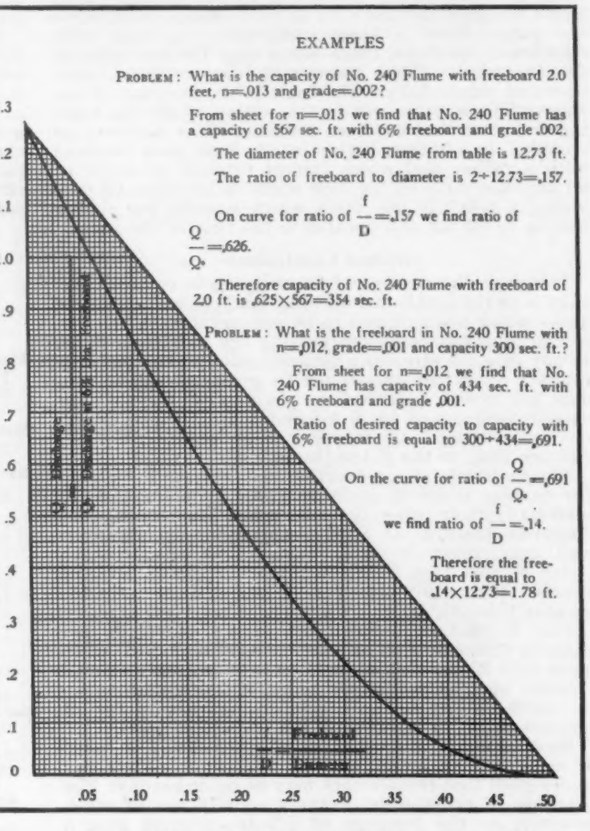

EXAMPLES
PROBLEM: What is the capacity of No. 240 Flume with freeboard 2.0 feet, n=.013 and grade=.002?
From sheet for n=.013 we find that No. 240 Flume has a capacity of 567 sec. ft. with 6% freeboard and grade .002.
The diameter of No. 240 Flume from table is 12.73 ft.
The ratio of freeboard to diameter is 2÷12.73=.157.
On curve for ratio of f/D =.157 we find ratio of Q/Q* =.626.
Therefore capacity of No. 240 Flume with freeboard of 2.0 ft. is .625×567=354 sec. ft.
PROBLEM: What is the freeboard in No. 240 Flume with n=.012, grade=.001 and capacity 300 sec. ft.?
From sheet for n=.012 we find that No. 240 Flume has capacity of 434 sec. ft. with 6% freeboard and grade .001.
Ratio of desired capacity to capacity with 6% freeboard is equal to 300÷434=.691.
On the curve for ratio of Q/Q* =.691 we find ratio of f/D =.14.
Therefore the freeboard is equal to .14×12.73=1.78 ft.
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50

Fig. 1. Ratios of discharge capacities for various ratios of freeboard to diameter.

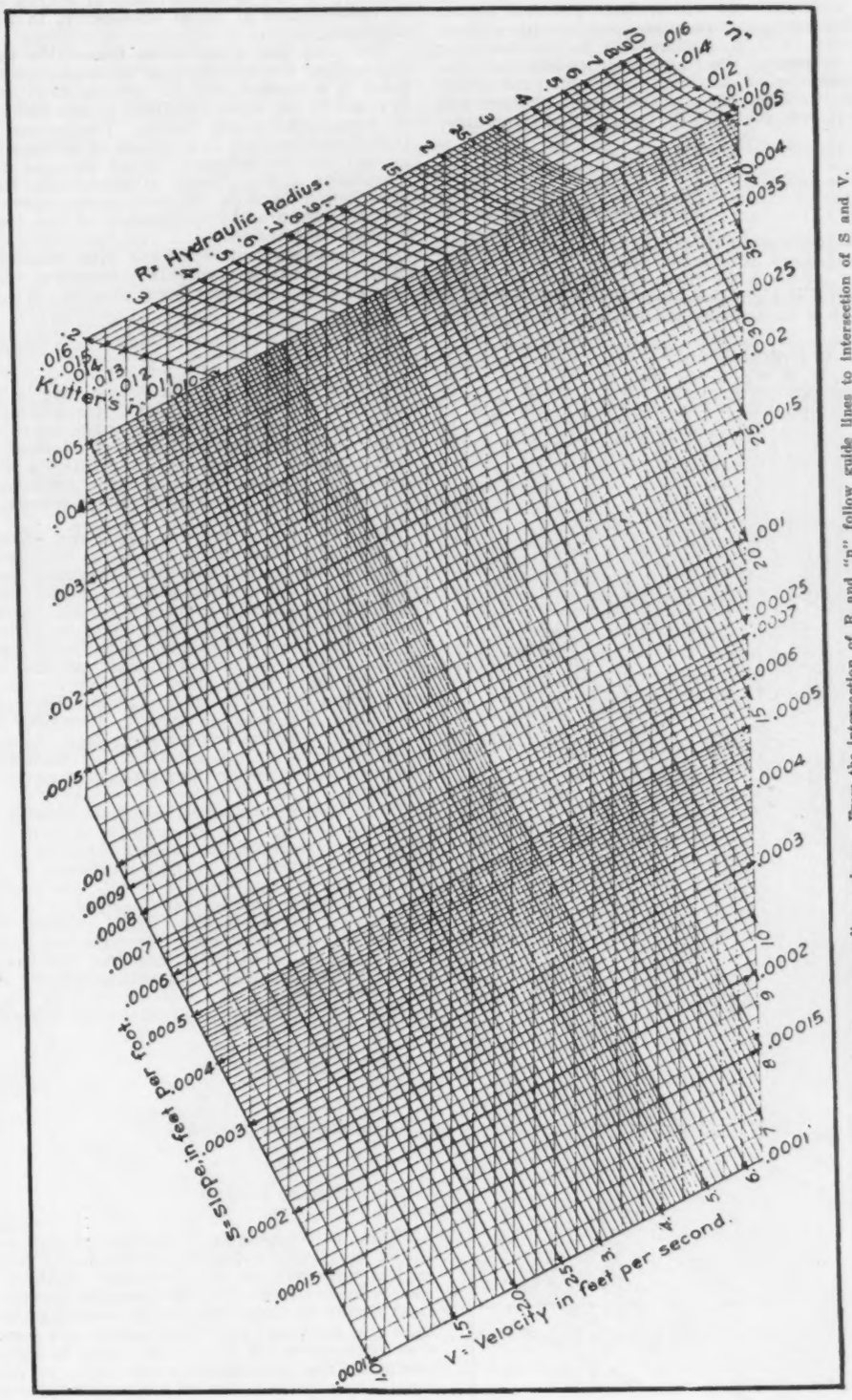


Fig. 2. Scobey chart for flumes on ordinary slopes. From the intersection of R and "n" follow guide lines to intersection of S and V.

Fig. 1 enable calculations to be readily made for other values of freeboard.

Recommended Values of "n" in Kutter Formula—Recommended values of the Kutter coefficient "n" vary somewhat with different authorities. For this reason Table V showing values recommended by either Etcheverry, Scobey or U. S. Reclamation Service has been prepared. In general the range is dependent upon the quality of construction, the alignment and on the ability to maintain the original condition of the channel and is about as follows for the different types of structures:

Wood	0.010 to 0.016
Concrete	0.012 to 0.016
Gunite	
Metal	0.012 to 0.014
	(Lennon type with smooth joints.)

Critical Velocity and Critical Depth—During the past ten years engineers have taken greater interest in the phenomenon known as "hydraulic jump" by which water traveling at high speep suddenly is elevated some distance with a consequent reduction in velocity. In obtaining a mathematical analysis by which the height and position of the jump could be predicted it was necessary to apply two fundamental laws of mechanics, namely, the law of conservation of energy and the law of conservation of linear momentum, to flow in open channels.

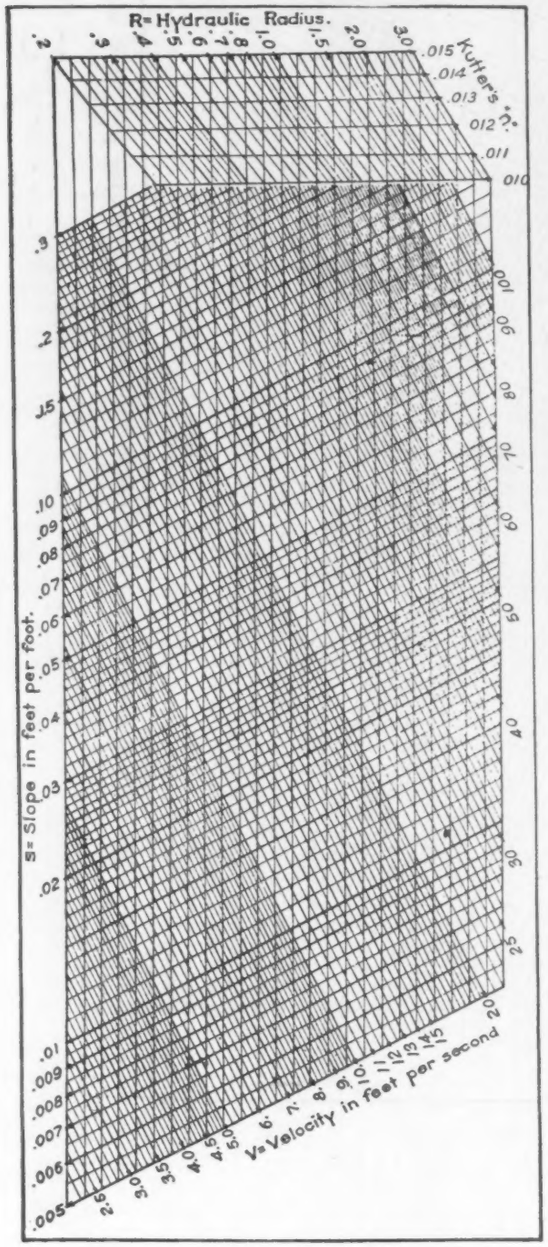


Fig. 3. Scobey chart for flumes on steep slopes. From the intersection of R and "n" follow guide lines to intersection of S. and V.

The first law appears as Bernoulli's theorem and states that the elevation of the water surface at any point in a channel plus the velocity head at that point is equal to the same functions at any other point plus or minus intervening losses. The second law states that the momentum of a system of paticles can only be altered by the influence of an external force. The magnitude of the change in momentum (for uniform acceleration between the two points under consideration) is measured by the product of this force and the time of its duration.

If the energy curve (depth plus velocity head) or $(d + hv)$ and the pressure momentum curve (pressure on cross-sectional area plus momentum) or

$$\frac{(P + Q V)}{g}$$

be plotted against depth of flow it may be found that (except for one particular depth) there is an upper and lower energy stage and an upper and lower momentum stage, each of which will give equal total energy or equal pressure plus momentum. This one exception is termed the critical depth and the velocity. At this depth water is flowing with minimum energy. Figure 5 illustrates this problem.

For any given change in depth the change in the energy curve is not proportional to the change in the pressure-plus-momentum curve, so it follows necessarily that a change in depth cannot occur without the introduction of some additional factor. A change between alternative energy stages may be effected by the application of an external force only, and a change between alternative momentum changes may be effected by a change in energy only. All other changes in depth involving a change in velocity require both an external force and a change in energy. However, where the velocity is near the critical value both the energy and the momentum curves are nearly horizontal and a slight change in energy may result in a material change in depth.

In designing any flume the critical velocity and critical depth should be investigated for if there is sufficient slope to support velocity higher than the critical, any slight obstruction or unusual roughness in the channel is likely to result in an hydraulic jump which might cause the water to flow over the sides of the flume. If the flow is to exceed the critical velocity, additional freeboard must be allowed to confine the water within the flume. In most cases, however, the shape of the channel can be changed and critical velocity avoided.

The simplest method of determining the value of critical velocity is from one of the following formulae:

For the general case— $$h_{vc} = \frac{V_c^2}{2g} = \frac{A}{2T}$$

For rectangular sections— $$h_{vc} = \frac{1}{2} d_c$$

For triangular sections— $$h_{vc} = \frac{1}{4} d_c$$

Figure 6 prepared by U. S. Reclamation Service shows the critical velocities and freeboard required for critical velocities on metal flumes. Table V and VI also extracted from U. S. Reclamation Service publications should be found valuable in obtaining the velocity head and discharge for critical depth and pressures on cross-sectional areas at various depths in semi-circular conduits. For rectangular sections or trapezoidal canals the solution is too simple to warrant preparation of special tables.

Freeboard Allowance—There have been several formulae presented for the determination of freeboard on flumes. Among these are the following:

(1) **U. S. Reclamation Service.**

Min. Freeboard $= 0.1\ D\ (0.9 + 0.1\ H_v)$.

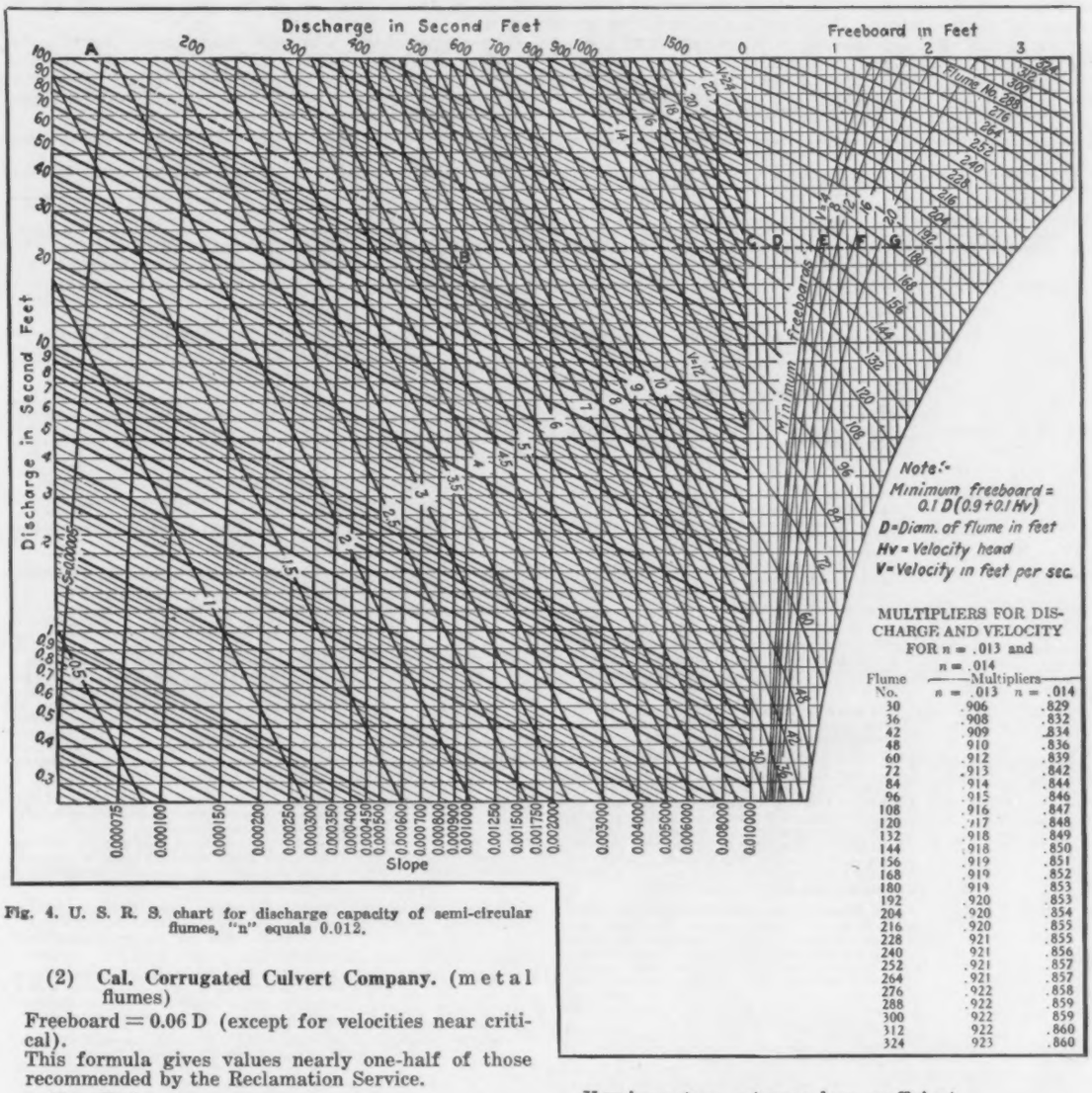
The freeboard is made a function of the diameter of flume and of the velocity, and automatically takes care of the effect of critical velocity.

Table II—Carrying capacities of metal flumes. Freeboard equals 0.06 x diam., "n" equals 0.012.

Drop in ft. per mile		.53	1.06	1.58	2 11	2.64	3.17	3.70	4.23	4.75	5.28	5.81	6.34	6.86	7.39	7.92	8.45	8.98	9.50	10.03	10.56	11.62	12.67	13.73	14.78	15.84	21.12	26.40	31.68	36.96	42.24	47.52	52.80	105.6	211.2	316.8	422.4	528.0
NUMBER	S	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0012	.0013	.0014	.0015	.0016	.0017	.0018	.0019	.0020	.0022	.0024	.0026	.0025	.003	.004	.005	.006	.007	.008	.009	.01	.02	.04	.06	.08	.10
12	V	.24	.37	.46	.54	.62	.68	.73	.79	.84	.89	.94	.98	1.01	1.05	1.09	1.12	1.16	1.20	1.23	1.26	1.32	1.35	1.43	1.50	1.56	1.81	2.01	2.21	2.38	2.53	2.70	2.86	4.05	5.73	7.08	8.12	9.08
	Q	.032	.050	.062	.073	.084	.092	.099	.107	.113	.120	.127	.132	.136	.142	.147	.151	.156	.162	.166	.170	.178	.186	.196	.203	.211	.244	.271	.298	.321	.344	.365	.386	.548	.780	.956	1.10	1.23
15	V	.29	.44	.55	.63	.74	.81	.88	.94	1.00	1.05	1.11	1.16	1.21	1.25	1.30	1.34	1.38	1.42	1.46	1.50	1.57	1.64	1.72	1.79	1.85	2.14	2.40	2.63	2.83	3.02	3.22	3.40	4.80	6.79	8.32	9.57	10.70
	Q	.061	.093	.116	.137	.156	.171	.186	.198	.211	.221	.234	.245	.255	.264	.274	.282	.291	.299	.306	.316	.331	.346	.363	.377	.390	.451	.506	.554	.597	.637	.679	.717	1.01	1.43	1.75	2.02	2.26
18	V	.33	.51	.64	.75	.85	.93	1.01	1.08	1.15	1.22	1.28	1.34	1.38	1.43	1.48	1.53	1.58	1.64	1.69	1.73	1.81	1.90	1.99	2.07	2.14	2.45	2.75	3.02	3.27	3.50	3.71	3.90	5.50	7.80	9.53	10.99	12.29
	Q	.100	.155	.194	.228	.258	.282	.307	.328	.349	.370	.388	.407	.419	.434	.449	.464	.480	.490	.513	.525	.549	.577	.604	.628	.649	.744	.835	.917	.992	1.06	1.13	1.18	1.67	2.37	2.90	3.33	3.73
21	V	.38	.58	.72	.85	.96	1.05	1.15	1.23	1.30	1.38	1.45	1.51	1.57	1.62	1.68	1.73	1.79	1.85	1.91	1.97	2.05	2.10	2.16	2.23	2.28	2.34	2.32	2.40	2.80	3.12	3.42	3.70	4.21	4.42	6.22	8.52	10.32	12.51	14.0
	Q	.157	.239	.297	.351	.396	.433	.473	.508	.537	.570	.599	.623	.646	.669	.694	.716	.739	.784	.804	.825	.842	.883	.925	.958	.981	1.16	1.29	1.41	1.53	1.63	1.74	1.82	2.57	3.65	4.47	5.16	5.78
24	V	.42	.64	.80	.94	1.06	1.16	1.26	1.36	1.43	1.52	1.60	1.66	1.73	1.79	1.85	1.91	1.97	2.03	2.10	2.16	2.26	2.31	2.37	2.47	2.56	2.63	3.07	3.44	3.76	4.07	4.36	4.63	6.89	9.62	12.05	13.86	15.40
	Q	.227	.345	.432	.507	.572	.626	.680	.734	.772	.820	.863	.896	.934	.966	.998	1.03	1.06	1.09	1.11	1.13	1.17	1.22	1.26	1.32	1.38	1.69	1.86	2.03	2.19	2.35	2.50	2.64	3.93	5.49	6.85	7.91	8.81
30	V	.51	.76	.95	1.11	1.25	1.38	1.49	1.60	1.69	1.79	1.89	1.96	2.04	2.11	2.18	2.26	2.33	2.39	2.48	2.54	2.67	2.73	2.80	2.91	3.03	3.09	3.63	4.06	4.44	4.80	5.15	5.47	8.14	11.36	14.23	16.37	18.19
	Q	.430	.681	.851	1.00	1.13	1.24	1.35	1.44	1.52	1.61	1.70	1.77	1.84	1.90	1.96	2.03	2.09	2.15	2.20	2.26	2.36	2.46	2.52	2.62	2.73	2.78	3.27	3.65	4.00	4.32	4.64	4.92	7.33	10.22	12.81	14.74	16.37
36	V	.59	.88	1.08	1.27	1.43	1.57	1.71	1.83	1.93	2.04	2.14	2.23	2.32	2.40	2.48	2.57	2.65	2.72	2.82	2.89	3.04	3.11	3.19	3.31	3.45	3.52	4.13	4.62	5.05	5.46	5.85	6.21	9.25	12.91	16.17	18.61	20.68
	Q	.784	1.11	1.36	1.60	1.81	1.98	2.16	2.31	2.44	2.57	2.70	2.81	2.93	3.03	3.13	3.24	3.34	3.43	3.56	3.64	3.83	3.92	4.03	4.17	4.35	4.44	5.21	5.83	6.38	6.89	7.38	7.83	11.66	16.28	20.39	23.47	26.07
42	V	.77	1.16	1.43	1.68	1.89	2.07	2.25	2.41	2.55	2.69	2.82	2.94	3.06	3.17	3.27	3.38	3.49	3.58	3.68	3.78	3.98	4.08	4.20	4.40	4.61	4.80	5.46	6.08	6.66	7.21	7.72	8.21	12.23	17.08	21.38	24.61	27.33
	Q	1.02	1.52	1.89	2.22	2.50	2.75	2.98	3.19	3.38	3.56	3.73	3.89	4.04	4.19	4.33	4.47	4.61	4.74	4.87	5.00	5.26	5.40	5.56	5.82	6.09	6.35	7.22	8.07	8.83	9.52	10.18	10.81	16.14	22.54	28.22	32.48	36.09
48	V	.87	1.28	1.58	1.85	2.09	2.29	2.49	2.67	2.82	2.98	3.12	3.25	3.38	3.51	3.62	3.74	3.86	3.96	4.07	4.17	4.40	4.51	4.64	4.86	5.09	5.25	6.03	6.73	7.38	7.99	8.56	9.09	13.55	18.92	23.68	27.26	30.28
	Q	1.13	1.76	2.20	2.58	2.90	3.18	3.45	3.71	3.92	4.14	4.33	4.51	4.69	4.86	5.03	5.19	5.36	5.50	5.65	5.80	6.09	6.26	6.44	6.75	7.06	7.31	8.37	9.35	10.26	11.10	11.88	12.61	18.82	26.28	32.91	37.68	41.87
60	V	.98	1.45	1.80	2.10	2.36	2.60	2.82	3.02	3.20	3.37	3.53	3.68	3.83	3.98	4.10	4.24	4.37	4.49	4.61	4.73	4.98	5.11	5.25	5.50	5.76	5.97	6.83	7.63	8.36	9.05	9.70	10.30	15.35	21.43	26.82	30.87	34.29
	Q	1.28	1.99	2.49	2.92	3.28	3.60	3.91	4.18	4.44	4.67	4.89	5.10	5.30	5.51	5.69	5.87	6.05	6.22	6.39	6.55	6.89	7.08	7.28	7.62	7.91	8.17	8.63	8.90	9.12	9.56	9.99	10.34	10.65	11.10	12.90	14.50	15.01	17.45	19.48	21.6
72	V	1.00	1.49	1.80	2.10	2.34	2.58	2.78	2.98	3.16	3.33	3.48	3.63	3.77	3.92	4.04	4.18	4.30	4.43	4.54	4.66	4.90	5.03	5.17	5.42	5.67	5.89	6.73	7.52	8.22	8.85	9.57	10.15	10.69	11.21	11.71	12.19	12.64	13.01	13.60	15.70	17.60	19.35	20.9	22.3	23.7	25.0	35.2	40.9	45.2
	Q	1.40	2.09	2.52	2.95	3.29	3.62	3.92	4.19	4.45	4.69	4.91	5.12	5.32	5.53	5.71	5.89	6.06	6.24	6.41	6.57	6.91	7.10	7.30	7.64	7.93	8.21	8.48	8.75	8.99	9.24	9.48	9.70	10.30	10.86	11.38	11.87	12.33	12.76	13.17	15.19	17.03	18.72	20.3	21.7	23.0	24.3	34.2	39.6	43.8
84	V	1.13	1.63	2.00	2.32	2.60	2.86	3.10	3.34	3.54	3.74	3.93	4.10	4.26	4.42	4.57	4.72	4.87	4.91	5.05	5.19	5.46	5.61	5.76	6.04	6.30	6.52	7.45	8.32	9.11	9.83	10.51	11.14	11.73	12.30	12.84	13.36	13.85	14.32	14.77	16.89	18.93	20.8	22.5	24.1	25.6	27.0	38.0	44.0	48.7
	Q	1.47	2.31	2.84	3.29	3.68	4.05	4.38	4.73	5.02	5.30	5.57	5.82	6.05	6.27	6.48	6.69	6.90	7.09	7.28	7.46	7.81	8.01	8.19	8.56	8.93	9.25	10.57	11.80	12.92	13.95	14.91	15.80	16.63	17.44	18.21	18.95	19.65	20.32	20.95	23.96	26.85	29.5	31.9	34.2	36.3	38.3	53.9	62.4	69.0
96	V	1.30	1.84	2.26	2.61	2.92	3.20	3.46	3.70	3.93	4.14	4.33	4.52	4.70	4.88	5.05	5.21	5.38	5.53	5.68	5.82	6.12	6.40	6.69	6.93	7.18	7.45	7.91	8.34	8.76	9.17	9.56	9.93	10.60	11.23	11.82	12.39	12.93	13.45	13.95	16.10	18.04	19.82	21.5	23.0	24.4	25.7	36.2	41.9	46.3
	Q	1.62	2.30	2.82	3.28	3.67	4.01	4.33	4.63	4.92	5.19	5.43	5.67	5.89	6.11	6.32	6.53	6.73	6.93	7.12	7.30	7.67	8.02	8.38	8.69	8.99	9.29	9.90	10.45	10.97	11.47	11.96	12.43	13.27	14.06	14.79	15.49	16.16	16.81	17.44	20.14	22.57	24.8	26.8	28.7	30.5	32.1	45.2	52.4	57.9
108	V	1.34	1.94	2.38	2.79	3.10	3.41	3.69	3.94	4.19	4.41	4.63	4.84	5.07	5.27	5.45	5.62	5.80	5.97	6.13	6.29	6.59	6.89	7.18	7.45	7.71	8.91	9.85	10.80	11.73	12.55	13.31	13.03	19.90	28.11	34.4	39.7	44.4
	Q	1.74	2.49	3.05	3.57	4.00	4.37	4.70	5.00	5.27	5.53	5.77	6.00	6.22	6.43	6.64	6.84	7.03	7.22	7.40	7.58	7.93	8.26	8.58	8.89	9.18	9.46	10.09	10.69	11.25	11.79	12.30	12.79	13.25	13.70	14.13	14.55	14.95	15.34	15.72	17.48	19.12	20.7	22.1	23.5	24.8	26.0	35.2	40.9	45.4
120	V	1.44	2.09	2.58	3.00	3.36	3.66	3.95	4.24	4.49	4.72	4.95	5.16	5.36	5.55	5.73	5.91	6.08	6.25	6.41	6.57	6.88	7.18	7.46	7.73	7.98	8.24	8.76	9.25	9.72	10.17	10.60	11.02	11.42	11.81	12.18	12.54	12.88	13.21	13.53	15.06	16.49	17.82	19.08	20.3	21.4	22.5	31.5	36.6	40.6
	Q	1.87	2.70	3.28	3.79	4.24	4.63	5.00	5.33	5.64	5.93	6.20	6.46	6.71	6.96	7.20	7.43	7.65	7.86	8.07	8.27	8.66	9.03	9.38	9.72	10.04	10.35	11.03	11.64	12.21	12.75	13.27	13.76	14.24	14.69	15.13	15.55	15.96	16.35	16.73	18.50	20.16	21.7	23.2	24.5	25.8	27.0	37.1	43.1	47.8
132	V	1.55	2.22	2.73	3.19	3.55	3.90	4.21	4.51	4.79	5.04	5.28	5.52	5.75	5.98	6.19	6.40	6.60	6.79	6.98	7.16	7.52	7.87	8.19	8.51	8.81	9.09	9.68	10.21	10.72	11.20	11.65	12.09	12.50	12.91	13.31	13.69	14.06	14.42	14.77	16.46	18.03	19.48	20.8	22.1	23.4	24.6	34.4	40.0	44.4
	Q	2.06	2.96	3.63	4.25	4.76	5.22	5.64	6.04	6.41	6.76	7.08	7.39	7.69	7.98	8.26	8.53	8.80	9.06	9.32	9.57	10.04	10.49	10.92	11.32	11.71	12.08	12.89	13.63	14.31	14.95	15.55	16.13	16.69	17.23	17.75	18.26	18.75	19.23	19.69	21.96	24.08	26.0	27.8	29.5	31.2	32.8	45.9	53.4	59.3
144	V	1.65	2.36	2.91	3.40	3.80	4.17	4.50	4.82	5.12	5.39	5.65	5.90	6.14	6.37	6.59	6.81	7.03	7.24	7.44	7.63	8.01	8.37	8.72	9.06	9.38	9.68	10.30	10.87	11.41	11.92	12.41	12.87	13.31	13.74	14.15	14.55	14.94	15.32	15.69	17.51	19.20	20.8	22.2	23.6	24.9	26.2	36.7	42.8	47.5
	Q	2.35	3.36	4.14	4.84	5.41	5.93	6.41	6.86	7.28	7.68	8.05	8.40	8.74	9.07	9.37	9.68	9.97	10.24	10.50	10.76	11.26	11.74	12.19	12.63	13.05	13.45	14.31	15.11	15.85	16.55	17.22	17.86	18.48	19.07	19.64	20.19	20.73	21.25	21.76	24.30	26.67	28.8	30.8	32.7	34.5	36.3	51.0	59.3	65.9
156	V	1.75	2.49	3.08	3.60	4.03	4.41	4.77	5.10	5.41	5.71	5.98	6.24	6.50	6.74	6.98	7.21	7.44	7.66	7.87	8.08	8.49	8.87	9.24	9.59	9.93	10.25	10.89	11.49	12.06	12.60	13.11	13.60	14.08	14.53	14.97	15.40	15.81	16.22	16.61	18.54	20.34	22.0	23.5	25.0	26.3	27.6	38.9	45.3	50.3
	Q	2.48	3.54	4.34	5.09	5.72	6.26	6.76	7.21	7.64	8.06	8.45	8.82	9.18	9.53	9.87	10.19	10.50	10.80	11.09	11.38	11.93	12.47	12.98	13.47	13.94	14.39	15.26	16.10	16.90	17.67	18.41	19.12	19.80	20.46	21.09	21.71	22.31	22.89	23.46	26.10	28.64	31.0	33.2	35.2	37.1	38.9	56.3	65.2	72.5
168	V	1.92	2.74	3.36	3.89	4.36	4.79	5.15	5.51	5.85	6.16	6.45	6.75	7.05	7.31	7.57	7.82	8.07	8.30	8.53	8.75	9.18	9.59	9.95	10.23	10.68	11.02	11.68	12.29	12.85	13.38	13.87	14.33	14.78	15.21	15.62	16.02	16.40	16.77	17.13	18.90	20.56	22.1	23.5	24.8	26.1	27.3	38.6	45.3	50.6
	Q	2.72	3.86	4.73	5.47	6.12	6.70	7.24	7.74	8.22	8.66	9.08	9.48	9.87	10.24	10.60	10.94	11.28	11.61	11.93	12.24	12.84	13.42	13.96	14.47	14.96	15.42	16.33	17.19	17.99	18.75	19.47	20.15	20.80	21.43	22.03	22.61	23.17	23.71	24.23	26.74	29.12	31.3	33.4	35.3	37.1	38.9	54.6	64.2	71.9
180	V	2.00	2.85	3.51	4.09	4.54	5.00	5.37	5.75	6.09	6.42	6.73	7.03	7.36	7.62	7.91	8.17	8.43	8.63	8.90	9.12	9.56	9.99	10.34	10.65	11.10	12.90	14.50	15.81	17.05	18.31	19.41	20.5	28.6	41.1	50.3	58.2	65.0
	Q	2.93	4.14	5.07	5.87	6.56	7.17	7.73	8.24	8.71	9.15	9.56	9.95	10.32	10.68	11.02	11.34	11.65	11.95	12.24	12.52	13.07	13.60	14.10	14.58	15.04	15.48	16.37	17.21	18.00	18.75	19.46	20.14	20.78	21.41	22.01	22.59	23.15	23.69	24.21	26.73	29.11	31.3	33.4	35.3	37.1	38.9	54.6	64.2	71.9
192	V	2.00	2.85	3.51	4.09	4.54	5.00	5.37	5.75	6.09	6.42	6.73	7.03	7.36	7.62	7.91	8.17	8.43	8.63	8.90	9.12	9.56	9.99	10.34	10.65	11.10	12.90	14.50	15.81	17.05	18.31	19.41	20.5	28.6	41.1	50.3	58.2	65.0
	Q	2.93	4.14	5.07	5.87	6.56	7.17	7.73	8.24	8.71	9.15	9.56	9.95	10.32	10.68	11.02	11.34	11.65	11.95	12.24	12.52	13.07	13.60	14.10	14.58	15.04	15.48	16.37	17.21	18.00	18.75	19.46	20.14	20.78	21.41	22.01	22.59	23.15	23.69	24.21	26.73	29.11	31.3	33.4	35.3	37.1	38.9	54.6	64.2	71.9
204	V	2.09	2.98	3.65	4.21	4.72	5.20	5.58	5.97	6.34	6.69	7.00	7.32	7.64	7.93	8.21	8.48	8.75	8.99	9.25	9.48	9.94	10.39	10.73	11.07	11.52	13.32	15.00	16.48	17.90	19.00	20.2	21.2	29.9	42.4	51.9	60.1	67.1
	Q	3.04	4.31	5.27	6.11	6.84	7.48	8.06	8.59	9.08	9.53	9.96	10.36	10.74	11.09	11.43	11.76	12.08	12.38	12.68	12.97	13.52	14.05	14.56	15.05	15.52	15.98	16.91	17.78	18.59	19.36	20.09	20.79	21.46	22.11	22.73	23.33	23.91	24.47	25.01	27.61	30.07	32.3	34.5	36.5	38.3	40.2	56.4	66.3	74.3
216	V	2.17	3.09	3.79	4.37	4.90	5.39	5.80	6.20	6.59	6.93	7.28	7.61	7.92	8.22	8.51	8.78	9.07	9.34	9.61	9.85	10.25	10.69	11.06	11.55	11.96	12.40	14.35	16.00	17.60	19.01	20.4	21.6	22.7	32.0	43.4	55.7	64.4
	Q	3.15	4.48	5.48	6.34	7.09	7.76	8.37	8.93	9.44	9.91	10.34	10.76	11.16	11.54	11.90	12.24	12.57	12.89	13.20	13.50	14.08	14.63	15.16	15.67	16.16	16.64	17.61	18.52	19.37	20.17	20.93	21.66	22.36	23.04	23.69	24.32	24.93	25.52	26.09	28.78	31.36	33.8	35.9	38.1	40.0	41.9	58.8	69.2	77.4
228	V	2.25	3.20	3.91	4.51	5.06	5.56	5.99	6.41	6.80	7.18	7.50	7.86	8.18	8.49	8.79	9.07	9.37	9.68	9.92	10.18	10.59	11.06	11.55	11.96	12.40	14.35	16.00	17.60	19.01	20.4	21.6	22.7	32.0	45.4	55.7	64.4	71.9
	Q	3.26	4.63	5.66	6.54	7.32	8.01	8.62	9.21	9.74	10.23	10.69	11.11	11.52	11.91	12.28	12.64	12.98	13.32	13.65	13.97	14.58	15.16	15.71	16.23	16.73	17.21	18.18	19.09	19.96	20.78	21.57	22.32	23.05	23.75	24.43	25.08	25.71	26.32	26.91	29.68	32.34	34.8	37.1	39.2	41.2	43.2	60.6	71.3	79.8
240	V	2.33	3.32	4.05	4.68	5.25	5.76	6.21	6.63	7.02	7.42	7.77	8.13	8.48	8.80	9.11	9.40	9.71	10.02	10.24	10.53	10.99	11.47	11.96	12.40	12.85	14.88	16.59	18.24	19.71	21.1	22.4	23.5	33.2	47.1	57.7	66.7	74.4
	Q	3.38	4.80	5.87	6.79	7.58	8.30	8.94	9.54	10.11	10.62	11.09	11.52	11.94	12.34	12.72	13.09	13.45	13.81	14.16	14.49	15.12	15.74	16.30	16.85	17.36	17.86	18.85	19.78	20.67	21.51	22.32	23.09	23.84	24.57	25.28	25.96	26.62	27.26	27.88	30.77	33.52	36.1	38.5	40.8	42.9	44.9	62.8	74.2	83.1
252	V	2.41	3.41	4.19	4.82	5.40	5.93	6.40	6.84	7.25	7.67	8.03	8.40	8.75	9.08	9.40	9.71	10.02	10.34	10.58	10.88	11.36	11.86	12.36	12.82	13.28	15.39	17.16	18.86	20.38	21.8	23.2	24.3	34.3	48.7	59.7	69.0	76.9
	Q	3.49	4.96	6.07	7.02	7.83	8.58	9.24	9.86	10.45	10.98	11.46	11.91	12.34	12.76	13.16	13.54	13.91	14.27	14.63	14.98	15.62	16.26	16.85	17.42	17.96	18.47	19.49	20.45	21.37	22.23	23.07	23.87	24.64	25.39	26.12	26.83	27.52	28.19	28.84	31.82	34.66	37.3	39.8	42.2	44.3	46.4	64.9	76.7	85.8
264	V	2.49	3.51	4.31	4.96	5.56	6.11	6.59	7.04	7.47	7.89	8.27	8.65	9.01	9.35	9.68	9.99	10.30	10.65	10.89	11.20	11.69	12.21	12.72	13.20	13.67	15.84	17.70	19.42	21.00	22.4	23.8	25.0	35.3	50.1	61.4	71.0	79.1
	Q	3.59	5.11	6.25	7.23	8.06	8.83	9.51	10.15	10.74	11.29	11.81	12.30	12.75	13.18	13.59	13.98	14.36	14.73	15.08	15.42	16.08	16.74	17.34	17.91	18.45	20.49	22.29	23.93	25.45	26.9	28.2	29.5	41.1	57.6	70.5	81.4	90.9
276	V	2.57	3.62	4.43	5.11	5.71	6.28	6.79	7.25	7.69	8.13	8.52	8.91	9.28	9.63	9.97	10.29	10.61	10.97	11.22	11.54	12.04	12.58	13.10	13.59	14.07	16.32	18.24	19.99	21.62	23.1	24.5	25.8	36.4	51.6	63.2	73.1	81.4
	Q	3.69	5.26	6.44	7.45	8.30	9.09	9.80	10.46	11.07	11.63	12.18	12.68	13.14	13.58	14.00	14.41	14.80	15.17	15.53	15.88	16.56	17.23	17.87	18.49	19.08	21.12	23.00	24.74	26.35	27.8	29.2	30.5	42.4	59.4	72.7	84.0	93.7
288	V	2.65	3.73	4.58	5.27	5.89	6.48	7.00	7.48	7.93	8.38	8.78	9.19	9.57	9.93	10.28	10.61	10.94	11.31	11.57	11.90	12.41	12.97	13.51	14.02	14.51	16.83	18.81	20.62	22.29	23.8	25.2	26.6	37.6	53.2	65.2	75.4	83.9
	Q	3.79	5.41	6.62	7.68	8.56	9.38	10.11	10.79	11.42	12.00	12.57	13.08	13.55	14.00	14.43	14.86	15.27	15.66	16.03	16.38	17.09	17.78	18.43	19.06	19.66	21.80	23.73	25.52	27.18	28.7	30.1	31.5	43.7	61.2	74.9	86.7	96.6
300	V	2.71	3.82	4.70	5.39	6.01	6.62	7.16	7.63	8.09	8.51	8.92	9.32	9.70	10.06	10.42	10.75	11.10	11.48	11.80	12.12	12.69	13.26	13.80	14.32	14.82	17.20	19.22	21.02	22.7	24.3	25.7	27.0	38.4	54.3	66.6	77.0	85.7
	Q	3.87	5.52	6.76	7.85	8.80	9.62	10.37	11.06	11.71	12.31	12.88	13.41	13.90	14.37	14.81	15.24	15.66	16.06	16.45	16.81	17.54	18.24	18.91	19.56	20.18	22.38	24.35	26.19	27.88	29.4	30.9	32.3	44.8	62.7	76.3	88.2	98.2
312	V	2.79	3.92	4.80	5.52	6.17	6.77	7.30	7.80	8.27	8.72	9.12	9.53	10.00	10.27	10.63	11.00	11.32	11.75	12.07	12.38	12.99	13.57	13.90	14.50	15.01	17.45	19.48	21.3	23.2	24.7	26.2	27.6	38.9	55.1	67.3	77.9	87.1
	Q	3.97	5.67	6.95	8.07	9.05	9.90	10.67	11.37

Table III—Carrying capacities of metal flumes. Freeboard equals 0.006 x diam., "n" equals 0.013.

Drop in ft. per mile		.53	1.06	1.58	2.11	2.64	3.17	3.70	4.22	4.75	5.28	5.81	6.34	6.86	7.39	7.92	8.45	8.98	9.50	10.03	10.56	11.62	12.67	13.73	14.78	15.84	21.12	26.40	31.68	36.96	42.24	47.52	52.80	105.6	211.2	316.8	422.4	528.0
NUMBER	S	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0012	.0013	.0014	.0015	.0016	.0017	.0018	.0019	.0020	.0022	.0024	.0026	.0028	.003	.004	.005	.006	.007	.008	.009	.01	.02	.04	.06	.08	.10
12	V	.27	.41	.52	.61	.68	.75	.82	.88	.93	.98	1.03	1.08	1.13	1.16	1.21	1.25	1.30	1.33	1.37	1.41	1.48	1.55	1.62	1.68	1.73	2.01	2.25	2.46	2.66	2.85	3.02	3.20	4.52	6.41	7.84	9.04	10.03
	Q	.036	.055	.070	.082	.092	.101	.111	.119	.126	.132	.139	.146	.153	.157	.163	.169	.176	.180	.184	.190	.200	.209	.219	.227	.234	.271	.304	.332	.359	.386	.408	.432	.610	.865	1.06	1.22	1.35
15	V	.32	.49	.61	.72	.81	.90	.98	1.04	1.10	1.17	1.23	1.28	1.34	1.39	1.44	1.49	1.55	1.59	1.63	1.68	1.76	1.84	1.92	1.99	2.06	2.37	2.67	2.92	3.15	3.37	3.58	3.78	5.34	7.61	9.27	10.70	11.90
	Q	.067	.103	.129	.152	.171	.190	.207	.219	.232	.247	.259	.270	.282	.293	.304	.314	.327	.335	.344	.354	.371	.388	.405	.419	.434	.500	.563	.616	.664	.710	.755	.797	1.13	1.60	1.95	2.26	2.51
18	V	.37	.56	.71	.83	.94	1.03	1.12	1.20	1.27	1.35	1.42	1.48	1.55	1.60	1.65	1.71	1.78	1.82	1.86	1.92	2.01	2.11	2.19	2.27	2.36	2.72	3.06	3.36	3.62	3.88	4.11	4.32	6.13	8.70	10.62	12.30	13.72
	Q	.112	.170	.215	.252	.285	.313	.340	.364	.385	.410	.431	.449	.470	.486	.501	.519	.540	.552	.564	.583	.610	.640	.665	.689	.716	.826	.929	1.02	1.10	1.18	1.25	1.31	1.86	2.64	3.22	3.73	4.16
21	V	.42	.64	.80	.94	1.06	1.17	1.27	1.35	1.44	1.53	1.60	1.67	1.75	1.80	1.87	1.93	2.00	2.04	2.10	2.16	2.27	2.38	2.47	2.57	2.66	3.06	3.45	3.77	4.09	4.35	4.63	4.88	6.91	9.85	12.00	13.85	15.49
	Q	.173	.264	.330	.388	.438	.483	.524	.557	.594	.632	.660	.689	.722	.743	.772	.797	.826	.842	.867	.892	.937	.982	1.02	1.06	1.10	1.26	1.42	1.56	1.69	1.80	1.91	2.01	2.85	4.07	4.95	5.72	6.39
24	V	.47	.71	.89	1.04	1.17	1.29	1.40	1.50	1.59	1.69	1.76	1.85	1.93	2.00	2.07	2.13	2.20	2.26	2.32	2.39	2.51	2.62	2.73	2.84	2.95	3.48	3.81	4.16	4.50	4.80	5.10	5.39	7.67	10.80	13.25	15.26	17.08
	Q	.254	.383	.480	.561	.631	.696	.755	.809	.858	.912	.950	.998	1.04	1.08	1.12	1.15	1.19	1.22	1.25	1.29	1.35	1.41	1.47	1.53	1.59	1.88	2.06	2.24	2.43	2.59	2.75	2.90	4.14	5.83	7.15	8.23	9.22
30	V	.56	.84	1.04	1.22	1.38	1.52	1.64	1.77	1.87	1.98	2.07	2.17	2.26	2.35	2.44	2.50	2.59	2.66	2.73	2.82	2.96	3.09	3.20	3.34	3.45	3.98	4.49	4.89	5.29	5.66	6.01	6.32	8.97	12.75	15.60	17.95	20.06
	Q	.472	.708	.877	1.03	1.16	1.28	1.38	1.49	1.58	1.67	1.75	1.83	1.91	1.98	2.06	2.11	2.18	2.24	2.30	2.38	2.50	2.61	2.70	2.82	2.91	3.36	3.79	4.12	4.46	4.77	5.07	5.33	7.56	10.7	13.2	15.1	16.9
36	V	.65	.97	1.19	1.40	1.58	1.74	1.88	2.02	2.14	2.25	2.37	2.48	2.59	2.69	2.79	2.87	2.95	3.04	3.12	3.21	3.38	3.52	3.67	3.80	3.95	4.54	5.12	5.57	6.02	6.34	6.86	7.21	10.24	14.48	17.75	20.5	22.9
	Q	.789	1.18	1.44	1.70	1.92	2.11	2.28	2.45	2.60	2.73	2.88	3.01	3.14	3.27	3.39	3.48	3.58	3.69	3.79	3.90	4.10	4.27	4.46	4.61	4.80	5.51	6.22	6.76	7.31	7.70	8.33	8.75	12.4	17.6	21.5	24.9	27.8
42	V	.73	1.08	1.34	1.58	1.77	1.95	2.10	2.26	2.40	2.52	2.67	2.79	2.90	3.00	3.11	3.21	3.31	3.41	3.51	3.61	3.78	3.95	4.10	4.27	4.41	5.11	5.73	6.24	6.73	7.22	7.68	8.10	11.40	16.22	19.82	22.8	25.6
	Q	1.21	1.79	2.21	2.61	2.93	3.22	3.47	3.74	3.97	4.17	4.41	4.61	4.79	4.96	5.14	5.31	5.47	5.64	5.80	5.97	6.25	6.53	6.78	7.06	7.29	8.45	9.47	10.3	11.1	11.9	12.7	13.4	18.8	26.8	32.8	37.7	42.3
48	V	.80	1.19	1.48	1.73	1.95	2.15	2.31	2.49	2.64	2.78	2.92	3.06	3.19	3.21	3.44	3.54	3.65	3.76	3.86	3.97	4.16	4.34	4.50	4.69	4.86	5.62	6.31	6.88	7.42	7.93	8.45	8.93	12.60	17.81	21.7	25.1	28.2
	Q	1.73	2.57	3.19	3.73	4.21	4.64	4.98	5.37	5.70	6.00	6.30	6.60	6.88	6.93	7.42	7.64	7.88	8.13	8.37	8.57	8.98	9.37	9.71	10.1	10.5	12.1	13.6	14.8	16.0	17.1	18.2	19.3	27.2	38.4	46.8	54.2	60.9
60	V	.95	1.40	1.73	2.03	2.28	2.51	2.70	2.90	3.07	3.24	3.41	3.56	3.72	3.84	4.01	4.11	4.25	4.39	4.50	4.62	4.84	5.05	5.25	5.46	5.65	6.57	7.32	8.05	8.65	9.26	9.84	10.37	14.70	20.7	25.5	29.3	32.9
	Q	3.20	4.72	5.84	6.85	7.69	8.47	9.11	9.78	10.4	10.9	11.5	12.0	12.5	13.0	13.5	13.9	14.3	14.8	15.2	15.6	16.3	17.0	17.7	18.4	19.1	22.2	24.7	27.2	29.2	31.2	33.2	35.0	49.6	69.8	86.0	98.8	110.9
72	V	1.08	1.60	1.97	2.30	2.58	2.84	3.05	3.26	3.46	3.67	3.86	4.04	4.21	4.36	4.53	4.66	4.81	4.96	5.10	5.23	5.50	5.71	5.96	6.18	6.42	7.42	8.28	9.11	9.82	10 50	11.10	11.75	16.55	23.6	28.9	33.3	37.2
	Q	5.25	7.77	9.57	11.2	12.5	13.8	14.8	15.8	16.8	17.8	18.7	19.6	20.4	21.2	22.0	22.6	23.4	24.1	24.8	25.4	26.7	27.7	28.9	30.0	31.2	36.0	40.2	44.2	47.7	51.0	53.9	57.1	80.4	114.6	140.4	161.7	180.7
84	V	1.22	1.78	2.20	2.56	2.87	3.15	3.40	3.62	3.86	4.08	4.30	4.47	4.67	4.82	5.02	5.16	5.33	5.50	5.67	5.81	6.09	6.34	6.62	6.85	7.10	8.21	9.15	10 05	10.82	11 62	12.26	13.05	18.32	26.2	32.0	37.0	41.4
	Q	8.06	11.8	14.5	16.9	19.0	20.8	22.5	23.9	25.5	27.0	28.4	29.5	30.9	31.9	33.2	34.1	35.2	36.4	37.5	38.4	40.3	41.9	43.8	45.3	46.9	54.3	60.5	66.4	71.5	76.8	81.0	86.3	121.1	173.2	211.5	244.6	273.7
96	V	1.35	1.97	2.41	2.82	3.16	3.48	3.73	4.00	4.23	4.49	4.72	4.91	5.12	5.33	5.50	5.69	5.88	6.03	6.21	6.39	6.69	6.98	7.28	7.52	7.80	9.04	10.03	11.02	11.98	12.80	13.50	14.38	20.2	28.7	35.1	40.6	45.5
	Q	11.7	17.0	20.8	24.3	27.3	30.0	32.2	34.5	36.5	38.8	40.8	42.4	44.2	46.0	47.5	49.1	50.8	52.1	53.6	55.2	57.8	60.3	62.9	64.9	67.3	78.0	86.6	95.1	103.4	110.5	116.6	124.2	174.4	247.8	303.0	350.5	392.8
108	V	1.46	2.13	2.61	3.03	3.41	3.74	4.02	4.30	4.57	48.2	5.08	5.30	5.51	5.71	5.91	6.10	6.30	6.49	6.58	6.86	7.18	7.49	7.82	8.10	8.39	9.71	10.78	11.88	12.89	13.77	14.55	15.48	21.6	30.9	37.8	43.5	48.7
	Q	16.0	23.3	28.5	33.1	37.3	40.7	43.9	47.0	50.0	52.7	55.5	57.9	60.2	62.4	64.6	66.6	68.8	70.9	71.9	75.0	78.4	81.8	85.4	88.5	91.7	106.1	117.8	129.8	140.8	150.5	159.0	169.1	236.0	335.4	413.0	475.3	5,34
120	V	1.57	2.27	2.80	3.25	3.65	4.00	4.30	4.60	4.89	5.16	5.42	5.67	5.91	6.10	6.33	6.53	6.73	6.95	7.14	7.33	7.68	8.01	8.38	8.67	9 00	10.40	11.60	12.70	13.76	14.75	15.60	16.50	23.2	33.0	40.2	46.6	52.1
	Q	21.2	30.6	37.8	43.8	49.2	54.0	58.0	62.0	66.0	69.6	73.1	76.5	79.7	82.3	85.4	88.1	90.8	93.8	96.3	98.9	103.6	108.1	113.0	117.0	121.4	140.3	156.5	171.3	185.6	199.0	210.4	222.6	313.0	445.2	542	629	703
132	V	1.68	2.45	2.99	3.48	3.90	4 25	4.60	4.91	5.21	5.51	5.81	6.04	6.30	6.51	6.77	6.98	7.19	7.41	7.64	7.83	8.19	8.55	8.94	9.25	9.60	11.05	12.37	13.60	14.68	15.74	16.68	17.60	24.8	35.2	43.1	49.6	55.8
	Q	27.4	40.0	48.8	56.8	63.7	69 4	75.1	80 1	85 0	89 9	94 8	98 6	102 8	106 3	110 5	113 9	119 0	120 9	124 7	127 8	133 7	139 6	145 9	151 0	156 7	180.4	201 9	222 0	239 6	256 9	272 3	287 3	404 8	575	703	810	911
144	V	1.78	2.58	3.15	3 66	4 12	4.50	4.85	5.19	5.52	5 81	6.11	6 39	6 65	6.89	7 15	7.37	7.60	7.82	8 07	8 27	8 63	9 02	9 45	9.76	10 15	11 68	13 04	14 29	15 50	16 59	17 59	18 55	26 2	37 2	45 6	52 5	58 8
	Q	34.6	50 1	61.2	71 1	80.0	87 4	94 2	100 8	107 2	112 9	118.7	124 1	129 2	133 8	138.9	143 2	147 6	151 9	156 8	160 6	167 3	175 2	183 6	189 6	197 2	226 9	253 3	277 5	301 1	322 3	341 7	360 3	509	723	886	1020	1142
156	V	1 89	2 73	3.32	3.86	4 34	4 74	5.10	5 46	5.81	6 13	6 44	6.72	7 01	7 23	7 51	7 77	8 00	8 24	8 48	8 70	9 09	9 51	9 93	10 26	10 62	12 29	13 70	15 08	16 30	17 50	18 50	19 50	27 5	39 1	47 9	55 3	62 0
	Q	43 1	62 2	75 7	88 0	98 9	108 1	116 3	124 5	132 5	139 8	146 8	153 2	159 8	164 8	171 2	177 1	182 4	187 9	193 3	198 3	207 2	216 8	226 4	233 9	242 1	280 2	312 3	343 8	371 6	399 0	421 8	444 6	627	891	1092	1261	1413
168	V	1 99	2 86	3 50	4 05	4 55	4 96	5 34	5 73	6 09	6 42	6 74	7 03	7 33	7 62	7 87	8 13	8 36	8 66	8 89	9 12	9 54	9 96	10 38	10 75	11 20	12 90	14 40	15 78	17 10	18 30	19 40	20 5	28 9	41 1	50 0	58 0	65 0
	Q	52 6	75 6	92 5	107 1	120 3	131 1	141 2	151 5	161 0	169 6	178 2	185 9	193 8	201 5	208 1	215 0	221 0	229 0	235 1	241 1	252 2	263 4	274 5	284 2	296 1	341 1	380 8	417 2	452 1	483 9	513	542	764	1047	1322	1534	1719
180	V	2 07	2 99	3 64	4 22	4 73	5 16	5 58	5 98	6 35	6 69	7 02	7 33	7 65	7 90	8 20	8 45	8 73	9 00	9 26	9 50	9 94	10 38	10 81	11 24	11 60	13 43	15 01	16 49	17 80	19 05	20 2	21 4	30 0	42 8	52 1	60 4	67 5
	Q	62 8	90 8	110 5	128 1	143 6	156 6	169 4	181 5	192 7	203 1	213 1	222 5	232 2	239 8	248 9	256 5	265 0	273 3	281 1	288 4	301 7	315 1	328 1	341 2	352 1	407 6	455 6	501	540	578	613	650	911	1299	1581	1833	2049
192	V	2 17	*3 13	3 80	4 41	4 94	5 40	5 82	6 24	6 63	7 00	7 34	7 67	7 98	8 28	8 60	8 85	9 10	9 40	9 68	9 92	10 38	10 80	11 28	11 75	12 20	14 00	15 67	17 20	18 55	19 98	21 1	22 3	31 5	44 5	54 5	63 0	70 2
	Q	74 9	108 1	131 2	152 3	170 6	186 5	210 0	215 5	229 0	241 7	253 5	264 9	275 6	285 9	297 0	305 6	314 3	324 6	334 3	342 6	358 5	373 0	389 6	405 8	421 3	483 5	541	594	641	690	729	770	1088	1537	1882	2176	2424
204	V	2 26	3 24	3 94	4 51	5 12	5 59	6 05	6 48	6 88	7 24	7 62	7 94	8 28	8 58	8 90	9 18	9 46	9 78	10 00	10 26	10 75	11 23	11 74	12 14	12 62	14 50	16 24	17 82	19 28	20 6	21 9	23 1	32 6	46 4	56 5	65 3	73 0
	Q	88 1	126 3	153 6	175 8	199 6	217 9	235 9	252 6	268 2	282 2	297 1	309 5	322 8	334 5	347 0	358 5	368 5	381 3	389 9	400 0	419 1	437 8	457 7	473 3	492 0	565	633	695	752	803	854	901	1270	1809	2203	2546	2846
216	V	2 36	3 38	4 10	4 76	5 32	5 81	6 30	6 74	7 15	7 53	7 91	8 27	8 60	8 92	9 26	9 54	9 85	10 14	10 39	10 64	11 15	11 65	12 13	12 62	13 07	15 05	16 88	18 51	20 0	21 5	22 8	24 1	34 0	48 0	58 9	68 0	76 0
	Q	103 1	147 7	179 2	208 0	232 5	253 9	275 4	294 6	312 5	329 1	345 7	361 5	375 9	389 9	404 7	417 0	429 2	443 2	454 1	465 0	487 3	509	530	552	571	659	738	809	874	940	997	1053	1486	2098	2574	2972	6093
228	V	2 44	3 50	4 24	4 92	5 49	6 01	6 50	6 96	7 39	7 79	8 19	8 53	8 88	9 20	9 56	9 87	10 16	10 45	10 75	11 00	11 55	12 06	12 52	13 01	13 51	15 60	17 43	19 10	20 7	22 1	23 5	24 9	35 2	49 7	60 9	70 2	78 3
	Q	118 8	170 4	206 5	239 6	267 4	292 7	316 5	338 9	359 9	379 4	398 8	415 4	432 4	448 0	465 6	480 6	491 8	509	523	536	562	584	610	634	658	760	849	930	1008	1076	1144	1213	1714	2420	2966	3419	3813
240	V	2 53	3 61	4 39	5 10	5 69	6 23	6 74	7 20	7 64	8 08	8 47	8 85	9 20	9 53	9 89	10 24	10 50	10 80	11 13	11 40	11 99	12 50	15 03	13 52	14 01	16 14	18 10	19 85	21 5	23 0	24 3	25 8	36 4	51 5	63 1	72 8	81 0
	Q	136 5	194 8	236 9	275 2	307 0	336 2	363 7	388 5	412 3	434 4	457 0	477 5	496 8	514	534	553	567	583	601	618	647	674	703	729	756	871	977	1071	1160	1241	1311	1392	1964	2779	3405	3928	4371
252	V	2 61	3 72	4 51	5 24	5 85	6 41	6 92	7 40	7 88	8 29	8 71	9 10	9 49	9 80	10 14	10 45	10 76	11 12	11 46	11 75	12 29	12 86	13 38	13 87	14 40	16 55	18 50	20 3	22 1	23 6	25 1	26 6	37 4	52 8	64 7	74 7	83 2
	Q	155 3	221 3	268 3	311 7	348 8	381 3	411 7	440 2	468 8	493 2	518	541	565	583	603	622	640	662	682	699	731	765	796	825	857	985	1101	1208	1315	1404	1493	1582	2225	3141	3849	4444	4950
264	V	2 69	3 83	4 66	5 40	6 02	6 60	7 13	7 64	8 10	8 52	8 99	9 40	9 73	10 10	10 46	10 77	11 12	11 50	11 77	12 08	12 63	13 23	13 75	14 29	14 85	17 10	19 10	21 0	22 8	24 3	25 9	27 2	38 4	54 5	66 8	77 0	85 9
	Q	175 6	250 1	304 3	352 6	393 0	430 9	465 5	498 8	529	556	587	614	635	659	683	703	726	751	768	789	825	864	898	933	970	1116	1247	1371	1489	1591	1691	1776	2507	3558	4361	5027	5608
276	V	2 76	3 94	4 79	5 52	6 18	6 79	7 31	7 82	8 31	8 75	9 21	9 60	10 00	10 37	10 70	11 05	11 40	11 76	12 10	12 40	13 02	13 57	14 10	14 60	15 20	17 50	19 50	21 5	23 3	24 9	26 5	28 0	39 3	55 6	68 4	78 9	88 0
	Q	197 0	281 2	341 8	393 9	441 0	484 6	522	558	593	624	657	685	714	740	764	789	814	839	863	885	929	968	1006	1042	1085	1249	1392	1534	1663	1777	1891	1998	2805	3968	4881	5631	6280
288	V	2 85	4 06	4 92	5 69	6 35	6 98	7 52	8 04	8 55	9 00	9 48	9 88	10 28	10 60	11 04	11 40	11 75	12 10	12 49	12 73	13 32	13 92	14 51	15 05	15 58	18 00	20 1	22 1	24 1	25 7	27 2	28 9	40 5	57 4	70 5	81 5	90 3
	Q	221 4	315 5	382 3	442 1	493 4	542	584	625	664	699	737	768	799	824	858	886	913	940	970	989	1035	1082	1127	1169	1211	1396	1562	1717	1863	1990	2113	2246	3147	4460	5478	6333	7016
300	V	2 92	4 17	5 04	5 84	6 51	7 13	7 72	8 24	8 75	9 24	9 71	10 10	10 50	10 92	11 32	11 70	12 08	12 40	12 75	13 07	13 70	14 30	14 92	15 45	16 03	18 49	20 6	22 6	24 6	26 3	28 0	29 5	41 6	58 7	71 9	83 1	92 2
	Q	246 2	351 6	424 9	492 4	549	601	651	695	738	779	819	852	885	921	954	986	1018	1045	1076	1102	1155	1206	1258	1303	1352	1559	1737	1905	2074	2217	2361	2487	3507	4949	6062	7006	7774
312	V	3 01	4 28	5 19	5 99	6 69	7 30	7 90	8 45	8 95	9 45	9 93	10 33	10 80	11 23	11 61	12 00	12 37	12 75	13 08	13 43	14 05	14 74	15 32	15 85	16 48	19 0	21 1	23 2	25 3	27 0	28 8	30 2	42 6	60 2	73 9	85 2	94 9
	Q	274 5	390 3	473 3	546	610	666	720	771	816	862	906	942	985	1026	1059	1094	1128	1163	1193	1225	1281	1344	1397	1445	1503	1733	1924	2116	2307	2464	2626	2754	3885	5490	6739	7770	8654
324	V	3 09	4 36	5 30	6 10	6 82	7 48	8 09	8 63	9 15	9 58	10 18	10 58	11 00	11 48	11 85	12 25	12 63	13 00	13 40	13 74	14 45	15 00	15 59	16 18	16 80	19 45	21 6	23 7	25 9	27 7	29 4	31 0	43 5	51 7	75 6	87 4	96 9
	Q	303 9	428 8	521	600	671	736	796	849	900	942	1001	1040	1082	1129	1165	1205	1244	1278	1318	1351	1421	1475	1533	1591	1652	1913	2124	2331	2547	2724	2891	3049	4278	5084	7435	8595	9529
336	V	3 16	4 47	5 41	6 26	6 99	7 65	8 27	8 83	9 38	9 90	10 39	10 80	11 25	11 70	12 12	12 56	12 93	13 33	13 68	14 00	14 70	15 38	15 95	16 52	17 16	19 76	22 0	24 2	26 3	28 2	30 0	31 7	44 4	62 9	77 1	89 2	98 8
	Q	334 2	472 8	572	662	739	809	875	934	992	1047	1099	1142	1190	1237	1282	1322	1367	1410	1447	1481	1555	1627	1687	1747	1815	2090	2327	2559	2782	2982	3173	3353	4696	6652	8154	9434	10449
348	V	3 24	4 57	5 55	6 40	7 14	7 82	8 45	9 02	9 59	10 19	10 65	11 05	11 50	11 95	12 40	12 80	13 23	13 60	14 00	14 38	15 08	15 62	16 40	16 90	17 60	20 2	22 5	24 8	27 1	29 1	30 8	32 5	45 5	64 3	78 8	91 2	101
	Q	367 6	519	630	726	810	887	959	1023	1088	1156	1208	1254	1305	1360	1407	1452	1503	1543	1589	1631	1711	1782	1861	1917	1957	2292	2553	2814	3075	3302	3494	3687	5162	7295	8940	10347	11459
360	V	3 30	4 65	5 64	6 52	7 27	7 97	8 60	9 19	9 73	10 30	10 80	11 30	11 76	12 20	12 66	13 07	13 50	13 90	14 30	14 60	15 31	16 00	16 62	17 25	17 90	20 6	22 9	25 2	27 6	29 5	31 3	33 1	46 2	65 5	80 3	93 0	103
	Q	400 6	565	685	792	883	968	1044	1116	1181	1250	1311	1372	1428	1481	1539	1587	1639	1688	1735	1773	1859	1942	2018	2094	2173	2501	2790	3060	3351	3582	3800	4019	5699	7952	9749	11291	12505
372	V	3 37	4 76	5 78	6 66	7 44	8 14	8 82	9 40	9 98	10 50	11 00	11 52	12 00	12 40	13 90	13 35	13 80	14 22	14 60	14 96	15 60	16 40	17 00	17 60	18 27	21 2	23 5	25 9	28 2	30 3	32 1	33 9	47 3	67 0	82 2	95 2	105
	Q	4472	617	749	863	964	1055	1143	1219	1291	1361	1434	1493	1556	1619	1802	1731	1789	1843	1893	1939	2022


Discharge in Second Feet
Freeboard in Feet
Discharge in Second Feet
Slope
Minimum freeboard
Note:-
Minimum freeboard = 0.1 D(0.9+0.1 Hv)
D=Diam. of flume in feet
Hv = Velocity head
V= Velocity in feet per sec.
MULTIPLIERS FOR DISCHARGE AND VELOCITY FOR n = .013 and n = .014

Flume No.	Multipliers n = .013	n = .014
30	.906	.829
36	.908	.832
42	.909	.834
48	910	.836
60	.912	.839
72	.913	.842
84	.914	.844
96	.915	.846
108	.916	.847
120	.917	.848
132	.918	.849
144	.918	.850
156	.919	.851
168	.919	.852
180	919	.853
192	.920	.853
204	.920	.854
216	.920	.855
228	921	.855
240	921	.856
252	.921	.857
264	.921	.857
276	.922	.858
288	.922	.859
300	922	859
312	922	.860
324	923	.860

Fig. 4. U. S. R. S. chart for discharge capacity of semi-circular flumes, "n" equals 0.012.

(2) **Cal. Corrugated Culvert Company.** (metal flumes)

Freeboard = 0.06 D (except for velocities near critical).

This formula gives values nearly one-half of those recommended by the Reclamation Service.

(3) **Etcheverry.**

$$\text{Freeboard in inches} = \frac{\text{depth of water in feet} + 2.}{12}$$

On curves the water usually has a tendency to climb on the outer wall so that additional freeboard should be provided for this case.

II—Inlets to Flumes

Hydraulic Calculations—In general the velocity in a flume is greater than that in the canal and it is necessary to provide sufficient entrance and velocity head to permit the water to accelerate to the higher velocity. The total drop in the water surface in the inlet transition is equal to the increment of velocity head plus an impact or entrance loss (usually expressed as a function of the velocity-head increment) plus a friction loss in the transition. Expressed in mathematical terms:

Formula I

$$\Delta H = \frac{V_2^2 - V_{12}}{2g} + K\left(\frac{V_2^2 - V_1^2}{2g}\right) + H_f$$

$$= (1 + K)\,\frac{V_2^2 - V_1^2}{2g} + H_f$$

where

V_2 = velocity in flume
V_1 = velocity in canal
K = impact or entrance loss coefficient
H_f = friction loss in transition.

It has been customary to assume a value of K between 15 per cent and 25 per cent but experience has shown that for well designed warped or bell-mouthed transition sections the loss is considerably less, 5 per cent readily being attained and 10 per cent being perfectly safe. It is better practice to use the smaller values for if the allowance for entrance loss is greater than it should be it is equivalent to adding an accelerating force in excess of that required. This will cause the water to over-speed either in the transition or in the upper end of the flume so that a disturbed flow results usually accompanied by one or more standing waves a short distance from the inlet. If the velocity in the flume for steady flow is near the critical velocity it is quite possible to obtain a "jump" which will not stay within the flume.

Length and Shape of Inlet—There is some difference of opinion among engineers as to the shape and length of the inlet. Julian Hinds in a current paper before the A.S.C.E. stated that the practice of the U. S. Reclamation Service has been to make the length of both inlets and outlets such that a straight line joining the flow line at the two ends of the transition will make an angle of about 12½ deg. with the axis of the structure. He also states that it now is generally conceded that for equal efficiency an inlet may be made shorter than an outlet for the same velocity change. F. C. Scobey recommends a bell-mouthed inlet of relatively short length, the radius of the bell-mouth being equal to one-

half the difference in the widths of water surface in the canal and in the flume. The Pacific Gas and Electric Company has used a length of 30 ft. on canals of from 300 to 500 sec.-ft. capacity and a length of 10 ft. or less on smaller canals. The recent designs on canals of from 100 to 200 sec.ft. in capacity have been a slight modification of the Scobey inlet and have been 10 ft. in length.

The shape of the best type Reclamation Service inlet after obtaining the length from the above criterion, is determined by assuming that the water-surface curve is a reversed parabola tangent at the ends of the tran-

TABLE IV-A—Values of "n" in Kutter's formula for wood flumes.

No.	"n"	Authority	Description
1	0.010	U.S.R.S.	Clean, straight channels newly lined with planed boards carefully laid.
2	0.011	U.S.R.S.	Construction as above but with alignment consisting of long tangents joined by gentle curves.
3	0.0115	Etcheverry	For wooden flumes of surfaced lumber when new and in excellent condition, boards all longitudinal, either smooth battens or smooth joints with no projecting calking, straight alignment, no curves, no angles, no silt or deposit.
4	0.012	U.S.R.S.	Clean, straight and regular channels of planed boards not in perfect order due to inferior workmanship or age; unplaned boards newly and carefully laid.
5	0.012	Scobey	Well constructed, clean flumes with surfaced lumber for both siding and battens, all lumber to run longitudinally. Alignment to consist of long tangents with gentle curves between. Construction to be such that the grade line will remain uniform, preventing sags and wavy alignment. If flumes are calked with oakum or other stuffing, care must be used that none projects into the water.
6	0.0125	Etcheverry	For wooden flumes of surfaced lumber when new and in excellent condition same as in (3) except slightly inferior or with flat curves or change in alignment by small angles or straight with smooth coat of tar; no silt or deposit.
7	0.013	Etcheverry	For wooden flumes of surfaced lumber in average good condition, or of rough lumber worn smooth by sediment and fine sand in water; straight in alignment, no silt or deposit.
8	0.013	Scobey	For well constructed, clean flumes of surfaced lumber and battens, following mountain contours, where the alignment will consist of about equal gentle curves and tangents. This value will also apply to flumes with alignment and grade as described in (5) but with vertical battens at intervals, with projecting calking or a slight amount of hardened asphalt or other waterproofing retarding the velocity.
9	0.014	Scobey	For flumes of very smooth interior, but with many bends or sharp curves. This value applies to those of (5) with a location such that a slight amount of hillside debris is unavoidable. Construction of type (5), but with cracks poured with any waterproofing material that hardens in tapering drops, is also liable to come in this type. For type (5) except that unsurfaced lumber is used.
10	0.014	U.S.R.S.	Unplaned boards not in perfect order due to inferior workmanship or age.
11	0.015	U.S.R.S.	As in (10) but with sharp curvature or with deposits of silt on bottom of channel.
12	0.015	Etcheverry	For wooden flumes of surfaced lumber in poor condition, over 10 years old, or with numerous changes in alignment made by sharp angles with short tangents (200 feet or less), or with old or transverse flooring.
13	0.015	Scobey	For flumes of unplaned lumber, but otherwise as of type (8). In the opinion of the writer, this is about the value to use for the usual grade of construction in a mountain canyon where the flume will get about the usual grade of maintenance with repairs made with irregular-shaped scraps of boards.
14	0.016	Etcheverry	For wooden flumes of rough lumber when new and not worn smooth or with many short tangents.
15	0.016	Scobey	For flumes of type (13) where sharp bends rather than curves are installed. For flumes lined with rough roofing material and for the ordinary grade of construction on a flume that is built and generally left to take care of itself. The kind of an organization that is to operate the flume will determine this factor.
16	Greater than 0.016	Scobey	For cases where the inside of the flume has changed so that its character as a wooden flume is practically lost. Debris accumulations, warped and loose battens, excessive sagging, with consequent accumulation of debris, all contribute to make values above .016 rather indeterminate, except by actual test.
17	0.018	Etcheverry	For wooden flumes in poor condition, rough asphalted, or projecting calking, or thickly slimed.
18	0.020	Etcheverry	For wooden flumes with flow nearly covered with sediment, sand, gravel, or scattered rocks, or with considerable slimy moss.

TABLE IV-B—Values of "n" in Kutter's formula; concrete flumes or canals.

No.	"n"	Authority	Description
1	0.010	U.S.R.S.	For clean, straight channels, newly lined with neat cement plaster, surfaces in perfect order.
2	0.011	U.S.R.S.	For construction as in (1), but with alignment consisting of long tangents joined by gentle curves.
3	0.012	U.S.R.S.	For clean, straight and regular channels, with concrete linings having steel troweled surfaces of 1:1 mortar carrying water practically free from silt; sand and cement plaster.
4	0.012	Etcheverry	(a) For concrete-lined canals having smooth, hard mortar finish, similar to sidewalk surface, uniform cross-section built to templet, joints smooth and flush with surface, long tangents, no curves for velocity exceeding about 4 feet per second and flat tapered curves for velocities under 4 feet. (b) For concrete flume or concrete-lined canals built with wet concrete mixture, poured between and carefully spaded against new planed matched lumber, painted smooth with cement grout or plastered smooth with troweled cement mortar, and for same alignment conditions as above.
5	0.012	Scobey	For the highest grade of material and workmanship and exceptionally good conditions. The surface of the lining to be as smooth to the hand as a troweled sidewalk. The expansion joints to be so well covered that they practically fulfill the same condition. The climate and water to be such that moss does not accumulate to any great extent. The water to be practically free from shifting material. The alignment to be composed of long tangents joined by spiraled curves, while the interior of the channel must be of uniform dimensions, true to grade throughout the cross-section.
6	0.0125	Etcheverry	(a) For flumes or concrete lining built of separate sections or slabs moulded or cast in steel forms and joined in place. (b) For concrete-lined canals, built without forms, but screed with rich grout to true surfaces; smooth joints even with surfaces, and for alignment conditions same as (4).
7	0.013	Etcheverry	For concrete-lined canals or flumes, built with forms and partly troweled or floated with cement mortar and for alignment conditions same as (4).
8	0.013	U.S.R.S.	For clean, regular channels of concrete having steel troweled surfaces of 1:1 mortar with a small amount of gentle curvature in alignment or carrying water with a small amount of silt.
9	0.013	Scobey	For construction as in (5), but with curves as in the usual mountain canyon. Same construction and alignment as in (5), but with small amount of sand or debris in water. Construction as in (10), but in very favorable alignment or for water that carries a small amount of fine silt that will eventually form a slick coat.
10	0.014	Scobey	For linings made by good construction under favorable conditions. The surface to be as left by smooth-jointed forms or to be roughly troweled. Joints to be good, but causing some retardation. Alignment to be about equal in curves and tangents, with no spirals between. The bed to be clean and sides free from rough deposits. In the opinion of the writer, this is the value to use for most linings on moderate-sized channels.
11	0.014	Etcheverry	For concrete-lined canals placed without forms, screed to true surfaces and floated to give a fairly smooth sand finish, for alignment conditions slightly inferior to those in (4).
12	0.014	U.S.R.S.	For clean, regular channels of concrete having wooden troweled or formed surfaces of good construction, the alignment consisting of tangents connected by gentle curves.
13	0.015	U.S.R.S.	For construction as in (12), but with sharp curvature or with deposits of silt on the bottom of the channel.
14	0.015	Etcheverry	For concrete-lined canals built with forms of planed lumber, partly roughened in construction, not plastered or grouted, for alignment conditions slightly inferior to those in (11) with a few sharp curves up to about 100 feet radius and 7 feet velocity. For linings as in (4), (6) and (7), with bottom partly covered with sand or gravel.
15	0.015	Scobey	For construction as in (10), but with sharp curves and clean bottom or moderate curves and much debris on the bottom but clean-cut sides.

TABLE IV-B—Values of "n" in Kutter's formula; concrete flumes or canals—Continued.

No.	"n"	Authority	Description
16	0.016	Scobey	For concrete as constructed by the average gang of laborers, using forms that leave prominent lines at the cracks, no finish coat being applied. Bed to have the usual small amount of rock fragments and patches of sand and gravel. Average amount of curvature. In climates where a rough deposit accumulates, as in southern California, a lining that originally had a value of "n" = 0.013 quickly assumes this type.
17	0.016	Etcheverry	For concrete-lined canals built with forms of rough lumber, no other finish, and for other conditions as in (14).
18	0.017	Etcheverry	For concrete-lined canals built without forms, rough construction, with wavy surfaces or shaped fairly smooth by tamping with backs of shovels.
19	0.017	Scobey	For roughly coated linings with uneven joints. This value is also applicable where rough deposits accumulate on the sides, and conditions of poor alignment.
20	0.018	Scobey	For very rough concrete with sharp curves and deposits of gravel and moss. A broken gradient, irregular cross-section and the like contribute to such a high value of "n."
21	0.018	Etcheverry	For concrete-lined canals as in (18) with considerable sand or gravel on the bottom or as in (14) and (17) with slime or moss deposit.

TABLE IV-C—Values of "n" in Kutter's formula; steel flumes.

No.	"n"	Authority	Description
1	0.011	U.S.R.S.	For clean, straight metal flumes of the smooth interior type carrying clear water and in perfect order.
2	0.0115	Etcheverry	For steel flumes, with countersunk joints flush with smooth interior surface; no silt or sediment.
3	0.012	Scobey	For steel flumes having countersunk joints between the various sheets of metal so that there is practically no added roughness presented to the water. Favorable alignment and clean.
4	0.012	U.S.R.S.	For metal flumes of the smooth interior type for water carrying a small amount of silt or with clear water and gentle curvature in alignment.
5	0.013	Etcheverry	For steel flumes with projecting bands or ribs at each joint; no silt or sediment; for velocities under 2 feet per second.
6	0.013	U.S.R.S.	For metal flumes of the smooth interior type having sharp curvature or used for water carrying a large amount of silt.
7	0.015	Scobey	For metal flumes having joints that project into the water section, presenting a shoulder every few feet that effectually retards the velocity. Favorable alignment and clean.
8	0.016	Etcheverry	For steel flumes with projecting bands or ribs at each joint; no silt or sediment; for velocities from 2 feet to 3.50 feet per second.
9	0.018	Etcheverry	For steel flumes with projecting bands or ribs at each joint; no silt or sediment; for velocities from 4 feet to 6 feet per second.
10	0.022	Etcheverry	For steel flumes made of corrugated sheets (Velocity 1.91).
11	0.022	Scobey	For steel flumes having regular corrugations at right angles to the axis of the flume. Favorable alignment and clean.

sition to the flow line in the canal and the flume respectively, the total drop in water surface being obtained from Formula I. With this assumption as to shape of water surface the velocity is calculated at about 5-ft. intervals and the transition warped or otherwise shaped to conform to these velocities. The selection of a reversed parabola as the shape of the water-surface curve, while admittedly arbitrary, was adopted to give smooth flow free from angles or sharp curves.

Effect of Critical Velocity on Inlet Design—Where the velocity in the flume is to be greater than critical it will be necessary to design the inlet in a somewhat different manner than that outlined above. It will be found advisable to hump the floor of the transition to make a control or "hydraulic notch" which will prevent draw-down in the canal above. At this point the water surface will pass through the critical depth. The upstream portion of the transition then is designed by assuming a smooth water surface tangent at the upper end to the water surface in the canal and passing through the critical depth at the control, the total drop to this point being obtained by Equation I. Between the control and the flume the depth is less than the critical and the total drop in this section is made to

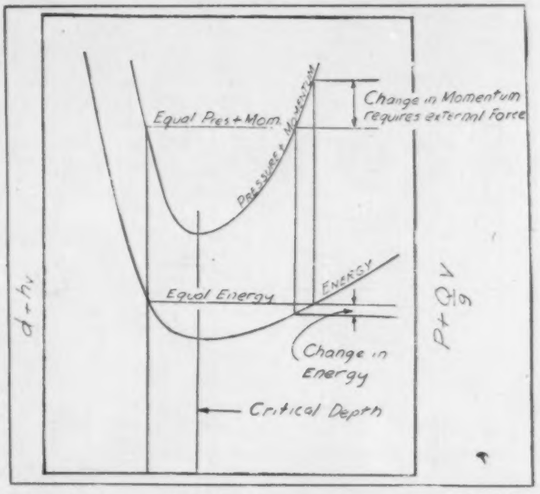


Fig. 5. Energy, pressure-plus-momentum curves and critical depth.

conform to an assumed water-surface curve approximating part of a reversed parabola, becoming tangent at the lower end to the normal water surface in the flume.

III—Flume Outlets

Hydraulic Calculations—In the ordinary installation there is a retardation of flow at the outlet of the flume and in a properly designed transition there will be a recovery of a part of the velocity head. Expressed mathematically the net regain of head is as follows:

$$\Delta H = \frac{V_1^2 - V_2^2}{2g} - K\left(\frac{V_1^2 - V_2^2}{2g}\right) - H_f$$

$$= (1 - K)\frac{V_1^2 - V_2^2}{2g} - H_f$$

The coefficient K in the past has been assumed to have values between 25 and 50 per cent, but the article by Julian Hinds states that this value may be less than 10 per cent and that 20 per cent is safe for design. Expressed differently, this means that while recovery of from 50 to 75 per cent of the difference in velocity heads has been considered possible, well designed transitions can be expected to give values of 80 to 90 per cent. Friction losses in the transition are to be deducted in obtaining the net recovery. Where there is possibility of the canal below the flume becoming clogged and if no allowance is made for this condition in making the flume setting it may be advisable to assume no recovery at the flume outlet. If this is done the backwater curve occasioned by the greater depth in the canal below will not enter the flume and encroach on the freeboard. As with the inlets, an allowance for a greater loss than that which actually exists will cause the water in the flume to speed up due to draw-down in the outlet transition.

Length and Shape of Outlets—As mentioned under "inlets" the Reclamation Service practice is to determine the length of outlet by drawing the straight line joining the flow line at the two ends at an angle of 12½ deg. with the axis of the flume. Here again the shape is determined by assuming the water surface to be a reversed parabola. Scobey suggests the use of flaring vertical walls making an angle of 30 deg. with the axis of the flume, and limiting the recovery to 50 per cent of the velocity-head increment, the simplicity of the outlet compensating for the 30 per cent additional loss. The Pacific Gas and Electric Company usually has made warped outlets twice as long as the inlets, giving a length of 20 ft. for small canals and 60 ft. for canals of about 400 sec.-ft. capacity.

Some of these outlets as well as the inlets have been

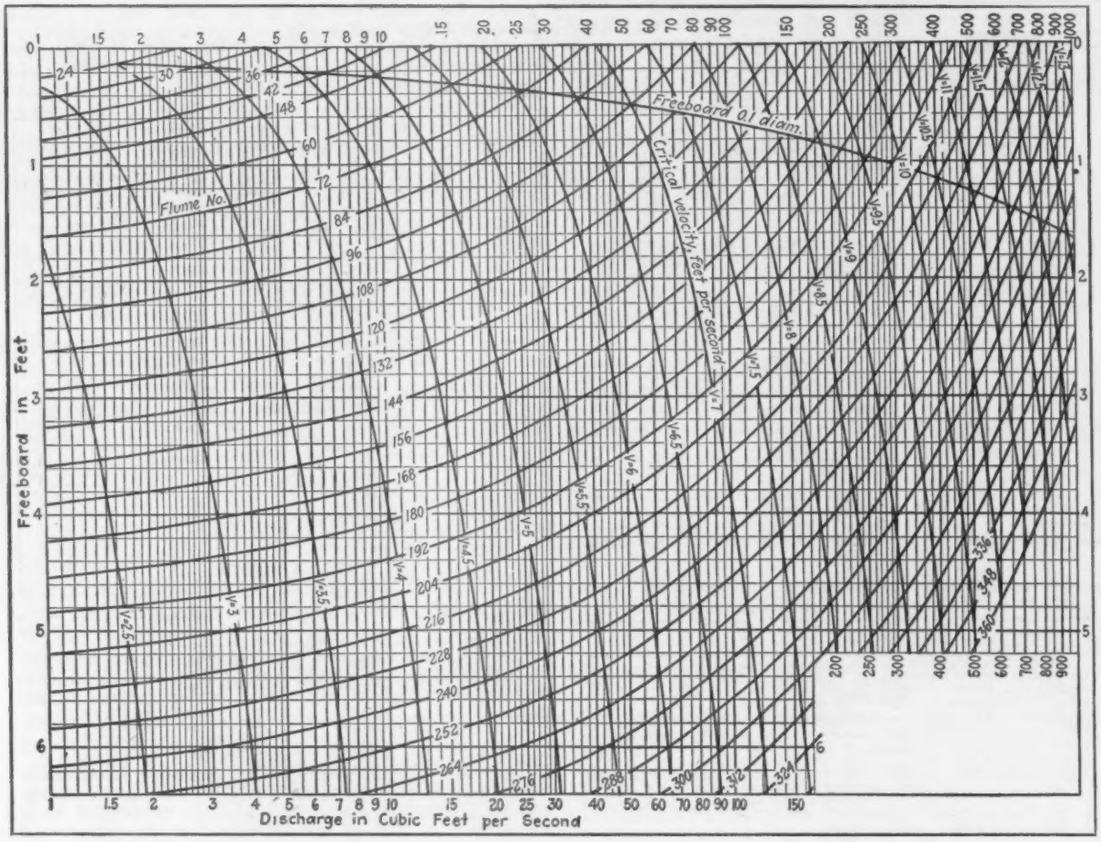


Fig. 6. Critical velocities and freeboards for critical depth in semi-circular flumes.

warped to conform to an assumed shape of water surface which usually has been a straight line rather than a curve of the type suggested by Hinds. This assumption admittedly is weak in that it requires abrupt changes in direction at the terminal points of the transition, a condition which cannot exist with free-flowing water.

Effect of Critical Velocity—Where the velocity in the flume is greater than critical the recovery in head usually is made through the medium of the hydraulic jump although by properly shaping the outlet this can be avoided. In this case a draw-down curve cannot effect the flow in the flume, also in most cases the effect of a slight increase in depth below the flume will affect only the position of the jump and not the flow in the flume.

The position and magnitude of the hydraulic jump in the outlet transition can be obtained approximately through the use of the energy and momentum curves already discussed. The problem is illustrated in Fig. 8 which shows a profile of an outlet in which the water from the flume enters at a depth less than critical. Above this profile are plotted water surface in the flume and canal, energy gradients for high and low stage in the transition, pressure-plus-momentum curves for high and low stage in the transition, minimum energy and critical depth. The position of the jump is determined by the intersection of the pressure-plus-momentum curves, the energy loss by the difference between the high and low-stage energy curves at this point and the water surface below the jump by deducting the velocity head from the high-stage energy gradient. If the pressure-momentum curves for low and high stage are made tangent to each other at the point of intersection the recovery of head is accomplished without the jump. If the canal downstream is in earth it will be necessary under these conditions to make analyses for more than one depth of flow in order to insure the occurrence of the jump on the paved portion of the transition.

It may be noted at this point that a jump of this type may occur in an entirely unexpected manner. On some recent installations in the Pacific Gas and Electric system the canal was designed conservatively, using a value of "n" = 0.030. When the water first was turned it was found that "n" is probably less than 0.025, resulting in a water surface drop of about 9 in. and providing about that much additional head for a structure only 200 ft. long. The result is a partial draw-down in the canal above with the upper end of the flume acting as a control, critical depth occurring at that point. The flow in the flume is very turbulent with standing waves at about 20-ft. intervals. At the outlet the water discharges into the transition at a velocity well above critical and a hydraulic jump occurs about 15 ft. from the end of the flume. Below the jump the water is comparatively quiet. To date this flume has carried successfully 80 per cent of design capacity without spilling over, but it may be necessary to check the flow below the structure to make it carry the full flow.

IV—Short and Long Flumes

A long flume may be defined as a flume in which steady or uniform flow is attained, i. e., the downstream control is located below the flume so that the backwater from the canal does not enter the fiume. A short flume is one which is entered by the backwater from the canal below the flume so that the velocity in the flume is not uniform throughout its length.

Unless the average flume is properly set it generally will be classified as a short flume requiring an investigation of the backwater curve which reduces the freeboard in the flume.

V—Typical Hydraulic Computations for Replacement of Old Flumes on Existing Canals:

When replacing flumes on existing canals, the following field data should be secured:

1. Profile of canal and old flume showing bottom of canal, profile of water surface for maximum discharge and profile of canal bank and top of old flume. This profile should include several hundred feet of canal above and below the structure.

2. Cross-section of canal and old flume throughout the length of the profile.

Let it be assumed that the following field data have been obtained:

1. Q = 500 sec.-ft.
2. Elevation bottom canal at upper end of flume = 100.65
3. Elevation bottom canal at lower end of flume = 100.00
4. Elevation water surface in canal—upper end of flume = 108.65
5. Elevation water surface in canal—lower end of flume = 108.00
6. Elevation top of bank—upper end of flume = 110.00
7. Elevation top of bank—lower end of flume = 109.50
8. Canal cross-section and grade indicate mean velocity of 2.5 ft. per sec. in canal
9. Total available fall (4)—(5) = 0.65 ft.
10. Length of flume = 500.00 ft.

It is intended to replace the old flume with a semi-circular metal type making it necessary to replace the transitions at the same time. The drop in the inlet transition will be assumed as 1.10 times and the rise in the outlet transition will be assumed as 0.75 times the difference in velocity heads in the flume and canal. Since the canal velocity is the same above and below the flume, the net loss in both transitions is equal to 35 per cent of the difference in velocity heads.

As a first approximation, assume that the velocity in the flume will be about 7 ft. per second. The transition losses therefore are

$$\frac{0.35}{64.4}(7^{-2} - 2.5^{-2}) = 0.23 \text{ ft.}$$

This gives a net available fall for the flume alone of $0.65 - 0.23 = 0.42$ ft., corresponding to $S = 0.00084$. The chart indicates that a No. 276 flume will very nearly fit the case, although it may be somewhat deficient in freeboard.

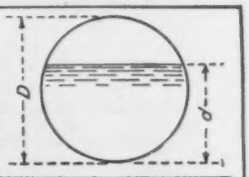
Checking over the No. 276 flume more closely: the carrying capacity is based on "n" = 0.012, the diameter (from Table No. 4) is 14.64 ft., and the area with 6 per cent freeboard is 71.36 sq.ft. Table No. 2 shows a capacity of 558 sec.-ft. with $S = 0.0008$ and a 6 per cent or 10½-in. freeboard on the flume. The freeboard by the U.S. Reclamation Service on Fig. 3 is nearly 18 in., and in this problem it will be assumed that a freeboard of approximately that magnitude is desired. The exact calculations for slope, elevations, etc., can only be made by trial as shown in the following table:

From the above table it is determined that the freeboard of 1.17 ft. with depth of 6.15 ft. fits the case in that the required and available slopes practically coinside. It remains, then, to establish the elevations for setting the structure and this is done best by fixing the lower end first, throwing the small discrepancy into the upper transition. The head regained in the outlet has been assumed to be 75 per cent of the difference in velocity heads or 0.57 ft. The elevation of the bottom of the flume at that end is therefore 108.00 minus 0.57 ft. minus 6.15 ft. or elevation 101.28. The elevation of

d/D	area/D²	wet. per./D	hyd. rad./D	d/D	area/D²	wet. per./D	hyd. rad./D
0.01	0.0013	0.2003	0.0066	0.51	0.4027	1.5908	0.2531
0.02	0.0037	0.2838	0.0132	0.52	0.4127	1.6108	0.2561
0.03	0.0069	0.3482	0.0197	0.53	0.4227	1.6308	0.2591
0.04	0.0105	0.4027	0.0262	0.54	0.4327	1.6509	0.2620
0.05	0.0147	0.4510	0.0326	0.55	0.4426	1.6710	0.2649
0.06	0.0192	0.4949	0.0389	0.56	0.4526	1.6911	0.2676
0.07	0.0242	0.5355	0.0451	0.57	0.4625	1.7113	0.2703
0.08	0.0294	0.5735	0.0513	0.58	0.4723	1.7315	0.2728
0.09	0.0350	0.6094	0.0574	0.59	0.4822	1.7518	0.2753
0.10	0.0409	0.6435	0.0635	0.60	0.4920	1.7722	0.2776
0.11	0.0470	0.6761	0.0695	0.61	0.5018	1.7926	0.2797
0.12	0.0534	0.7075	0.0754	0.62	0.5115	1.8132	0.2818
0.13	0.0600	0.7377	0.0813	0.63	0.5212	1.8338	0.2839
0.14	0.0668	0.7670	0.0871	0.64	0.5308	1.8546	0.2860
0.15	0.0739	0.7954	0.0929	0.65	0.5404	1.8755	0.2881
0.16	0.0811	0.8230	0.0986	0.66	0.5499	1.8965	0.2899
0.17	0.0885	0.8500	0.1042	0.67	0.5594	1.9177	0.2917
0.18	0.0961	0.8763	0.1097	0.68	0.5687	1.9391	0.2935
0.19	0.1039	0.9020	0.1152	0.69	0.5780	1.9606	0.2950
0.20	0.1118	0.9273	0.1206	0.70	0.5872	1.9823	0.2962
0.21	0.1199	0.9521	0.1259	0.71	0.5964	2.0042	0.2973
0.22	0.1281	0.9764	0.1312	0.72	0.6054	2.0264	0.2984
0.23	0.1365	1.0003	0.1364	0.73	0.6143	2.0488	0.2995
0.24	0.1449	1.0239	0.1416	0.74	0.6231	2.0714	0.3006
0.25	0.1535	1.0472	0.1466	0.75	0.6318	2.0944	0.3017
0.26	0.1623	1.0701	0.1516	0.76	0.6404	2.1176	0.3025
0.27	0.1711	1.0928	0.1566	0.77	0.6489	2.1412	0.3032
0.28	0.1800	1.1152	0.1614	0.78	0.6573	2.1652	0.3037
0.29	0.1890	1.1373	0.1662	0.79	0.6655	2.1895	0.3040
0.30	0.1982	1.1593	0.1709	0.80	0.6736	2.2143	0.3042
0.31	0.2074	1.1810	0.1755	0.81	0.6815	2.2395	0.3044
0.32	0.2167	1.2025	0.1801	0.82	0.6893	2.2653	0.3043
0.33	0.2260	1.2239	0.1846	0.83	0.6969	2.2916	0.3041
0.34	0.2355	1.2451	0.1891	0.84	0.7043	2.3186	0.3038
0.35	0.2450	1.2661	0.1935	0.85	0.7115	2.3462	0.3033
0.36	0.2546	1.2870	0.1978	0.86	0.7186	2.3746	0.3026
0.37	0.2642	1.3078	0.2020	0.87	0.7254	2.4038	0.3017
0.38	0.2739	1.3284	0.2061	0.88	0.7320	2.4341	0.3008
0.39	0.2836	1.3490	0.2102	0.89	0.7384	2.4655	0.2996
0.40	0.2934	1.3694	0.2142	0.90	0.7445	2.4981	0.2980
0.41	0.3032	1.3898	0.2181	0.91	0.7504	2.5323	0.2963
0.42	0.3130	1.4101	0.2220	0.92	0.7560	2.5681	0.2944
0.43	0.3229	1.4303	0.2257	0.93	0.7642	2.6061	0.2922
0.44	0.3328	1.4505	0.2294	0.94	0.7662	2.6467	0.2896
0.45	0.3428	1.4706	0.2331	0.95	0.7707	2.6906	0.2864
0.46	0.3527	1.4907	0.2366	0.96	0.7749	2.7389	0.2830
0.47	0.3627	1.5108	0.2400	0.97	0.7785	2.7934	0.2787
0.48	0.3727	1.5308	0.2434	0.98	0.7816	2.8578	0.2736
0.49	0.3827	1.5508	0.2467	0.99	0.7841	2.9412	0.2665
0.50	0.3927	1.5708	0.2500	1.00	0.7854	3.1416	0.2500

Table V—Area, wetted perimeter, and hydraulic radius of partially filled circular conduit sections.

D= Diameter of circle.
d= Depth of water.
hv= Velocity head for a critical depth of d.
Q= Discharge when the critical depth is d.
P= Pressure on cross section of water prism in cubic units of water. To get P in pounds, when d and D are in feet, multiply by 62.5. See explanation, page 48-d.



d/D	hv/D	Q/D^2.5	P/D^3	d/D	hv/D	Q/D^2.5	P/D^3	d/D	hv/D	Q/D^2.5	P/D^3
1	2	3	4	1	2	3	4	1	2	3	4
.01	.0033	.0006	.0000	.34	.1243	.0657	.0332	.67	.2974	2.4464	.1844
.02	.0067	.0025	.0000	.35	.1284	.7040	.0356	.68	.3048	2.5192	.1700
.03	.0101	.0055	.0001	.36	.1326	.7433	.0381	.69	.3125	2.5912	.1758
.04	.0134	.0096	.0002	.37	.1368	.7836	.0407	.70	.3204	2.6656	.1816
.05	.0168	.0153	.0003	.38	.1411	.8249	.0434	.71	.3286	2.7416	.1875
.06	.0203	.0220	.0005	.39	.1454	.8671	.0462	.72	.3371	2.8188	.1935
.07	.0237	.0298	.0007	.40	.1497	.9103	.0491	.73	.3459	2.8977	.1996
.08	.0271	.0389	.0010	.41	.1541	.9545	.0520	.74	.3552	2.9783	.2058
.09	.0306	.0491	.0013	.42	.1586	.9996	.0551	.75	.3648	3.0607	.2121
.10	.0341	.0605	.0017	.43	.1631	1.0458	.0583	.76	.3749	3.1450	.2185
.11	.0376	.0731	.0021	.44	.1676	1.0929	.0616	.77	.3855	3.2314	.2249
.12	.0411	.0868	.0026	.45	.1723	1.1410	.0650	.78	.3967	3.3200	.2314
.13	.0446	.1016	.0033	.46	.1769	1.1899	.0684	.79	.4085	3.4112	.2380
.14	.0482	.1178	.0038	.47	.1817	1.2399	.0720	.80	.4210	3.5050	.2447
.15	.0517	.1347	.0045	.48	.1865	1.2908	.0757	.81	.4343	3.6016	.2515
.16	.0553	.1530	.0053	.49	.1914	1.3427	.0796	.82	.4485	3.7021	.2584
.17	.0589	.1724	.0061	.50	.1964	1.3955	.0833	.83	.4638	3.8081	.2653
.18	.0626	.1928	.0070	.51	.2014	1.4493	.0873	.84	.4803	3.9144	.2723
.19	.0662	.2144	.0080	.52	.2065	1.5041	.0914	.85	.4982	4.0276	.2794
.20	.0699	.2371	.0091	.53	.2117	1.5598	.0956	.86	.5177	4.1465	.2865
.21	.0736	.2609	.0103	.54	.2170	1.6164	.0998	.87	.5393	4.2721	.2938
.22	.0773	.2857	.0115	.55	.2224	1.6735	.1042	.88	.5632	4.4056	.3011
.23	.0811	.3116	.0128	.56	.2279	1.7327	.1087	.89	.5900	4.5486	.3084
.24	.0848	.3386	.0142	.57	.2335	1.7923	.1133	.90	.6204	4.7033	.3158
.25	.0887	.3667	.0157	.58	.2393	1.8530	.1179	.91	.6555	4.8725	.3233
.26	.0925	.3957	.0173	.59	.2451	1.9146	.1227	.92	.6966	5.0608	.3308
.27	.0963	.4259	.0190	.60	.2511	1.9773	.1276	.93	.7459	5.2726	.3384
.28	.1002	.4571	.0207	.61	.2572	2.0409	.1326	.94	.8055	5.5183	.3460
.29	.1042	.4893	.0226	.62	.2635	2.1057	.1376	.95	.8841	5.8118	.3537
.30	.1081	.5225	.0255	.63	.2699	2.1716	.1428	.96	.9885	6.1787	.3615
.31	.1121	.5568	.0266	.64	.2765	2.2386	.1481	.97	1.1410	6.6093	.3692
.32	.1161	.5921	.0287	.65	.2833	2.3067	.1534	.98	1.3958	7.4098	.3770
.33	.1202	.6284	.0309	.66	.2902	2.3760	.1589	.99	1.9700	8.8263	.3848
								1.00			.3927

49183°—27——4

Table VI—Velocity head and discharge at critical depths and static pressures in circular conduits partly full.

TABLE VII—Calculation data.

1	2	3	4	5	6	7	8	9	10	11
Freeboard	Depth	d/D	Area/D²	Area	Hyd. Rad./D	R	V	Required Slope	Transition Losses	Available Slope
None	7.32	0.50	0.3927	84.2	0.2500	3.66				
0.97	6.35	0.44	0.3328	71.4	0.2294	3.35	7.00	0.00064	0.23	0.00084
1.02	6.30	0.43	0.3229	69.2	0.2257	3.30	7.23	0.00070	0.25	0.00080
1.17	6.15	0.42	0.3130	67.1	0.2220	3.25	7.45	0.00075	0.27	0.00076
1.32	6.00	0.41	0.3032	65.0	0.2181	3.20	7.70	0.00082	0.29	0.00072
1.46	5.86	0.40	0.2934	62.7	0.2142	3.14	7.97	0.00085	0.31	0.00068

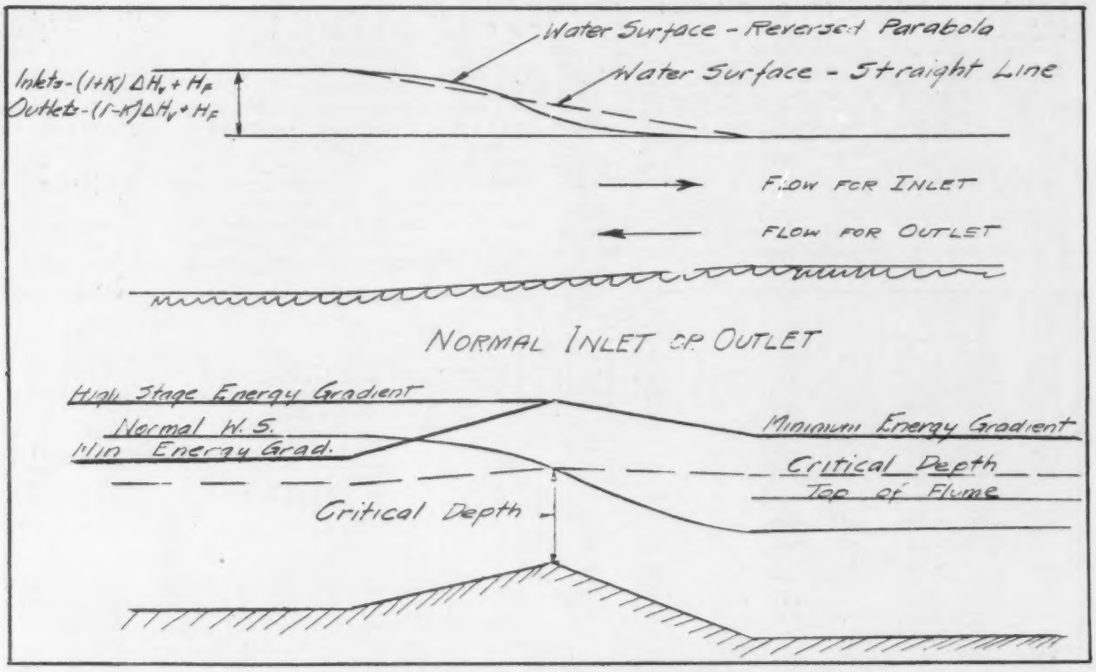


Fig. 7. Effect of critical velocity upon inlet design.

the bottom of the flume at the inlet end is (500 times 0.00075) ft. higher or 101.66. The drop in the water surface at the inlet is by assumption 1.1 times the difference in velocity head, or 0.84 ft. The water surface in the canal at the upper end of the inlet transition therefore is 101.66 plus 6.15 plus 0.84 or at elevation 108.65, which checks the field data.

In many installations it is possible to select the next smaller size flume, setting it on a slightly steeper gradient and permitting a slight encroachment upon the freeboard in the canal upstream from the flume, but care should be used to make sure that all points of design have been considered carefully. Also the cost of installing the next larger size should be checked up. An increased quantity of water at the plant frequently results in a larger output, with the carrying capacity of the conduit line as the "neck of the bottle."

Mechanics—Metal

This topic discussion is intended to show the best accepted practices used in the design of the mechanical features of metal flumes. It is to be assumed that all the hydraulic features have been considered carefully and that it has also been determined to use a semicircular metal flume. The substructure construction must be considered in conjunction and in this report it is considered that the metal substructure for the support of the metal flume falls within this subdivision.

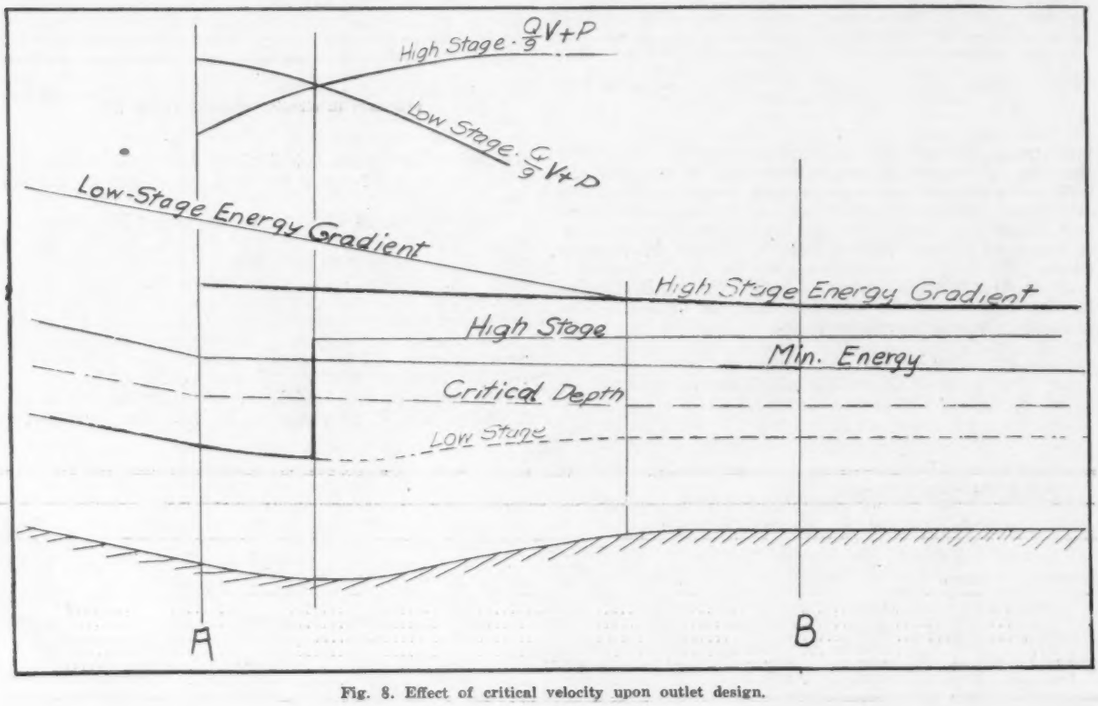


Fig. 8. Effect of critical velocity upon outlet design.

The general conditions of type of ground, accessibility, size, spans and any other items which a careful full study of the entire problem will disclose must be the controlling features in deciding on the substructure materials and design to use.

The following outline is proposed as a guide for the design of metal flumes and metal substructures:

(A) Metal Flumes

Types—Metal flumes usually are semi-circular in shape although there are one or two instances in which they have been constructed with a rectangular box section. At the present time, however, the box type is not used.

There are two general types of semi-circular metal flumes, those with rough interior and those with smooth interior. Rough-interior flumes have projections of one kind or another on the interior surface. Smooth-interior flumes are so constructed that all the clamping and supporting members on the interior of the flume are placed in beads sunk into the sheet metal so as to come flush with the interior surface. This secures a smooth interior surface which offers no obstruction to the flow of the water. There is considerable difference in the carrying capacity in these two general types of flumes which depends upon the coefficient of friction.

In rough-interior flumes, the coefficient of friction depends upon the amount and kind of projection on the interior surface. The values of "n" vary from about 0.014 in riveted flumes to 0.018 in flumes having an inside projecting clamping member at the joints. In smooth-interior types the coefficient of friction depends upon alignment, curvature and smoothness of paint coating, and varies from "n"= 0.011 for unpainted flumes with good alignment at center and along top edges, to "n" = 0.013 for painted flumes on sharp curves or where bulges occur between the joints along the top edges.

Other factors which enter into the differences between the different types of smooth interior flumes are joint leakage, effect of contraction and expansion due to changes in temperature, ease of assembly, freedom from injury to galvanized coating at joints, workmanship and uniformity, and quality of materials used.

Stresses—Load stresses are the dead load and wind load. The dead load consists of the weight of the materials in the metal flume plus the weight of the water carried and is maximum for the flume full of water. The wind load against the curved surface of the metal flume will be practically the same as that for chimneys which gives 25 lb. per sq.ft. of vertical projection for a wind velocity of 100 miles per hr., which would be about the maximum in most localities and would be much less in protected areas or for wind direction which was not at right angles to the center line of the flume.

Temperature Stresses—In rigid structures such as rivited flumes or where the joints proivde for no movement, the stresses due to contraction and expansion, must be taken care of by expansion joints placed at regular intervals. In this type of joint which provides for contraction and expansion the only occasion requiring expansion joints is when supported on steel substructures in which expansion joints are used and where considerable movement takes place at one point.

Metal Substructures

Types—Steel substructures are subject to a wide variety of design. The usual design is much the same type as to position of members as wood substructures. The structural shapes best adapted for the stringers are channels; for the posts, two angles with unequal legs, long legs back-to-back for small size flumes and H-columns for large sizes. The knee-braces, cross-braces and cross-bars usually are constructed from angles. The design should include a study of erection methods and sectionalizing for transportation, when any of the members are shop rivited.

Stresses—The load stresses are dead load and wind load. The maximum dead load consists of the combined weights of the metal flume, the steel structure and the weight of the flume full of water. The maximum wind load for a velocity of 100 miles per hr. will be 25 lb. per sq.ft. for its projected area in elevation on the flume and 40 lb. per sq.ft. of exposed surface for the substructure. The unit stresses and design conditions contained in the American Institute of Steel Construction should govern all metal design.

The temperature stresses in metal substructures for metal flumes are caused by contraction and expansion from temperature changes. On flumes located on curves this may be ignored as the contraction and expansion is taken care of by the curves. On tangents, if the substructure is a trestle, the most desirable way is to provide expansion joints in the girders at spaces close enough together to prevent any great amount of movement at any one point so it will not be necessary to provide expansion joints in the metal flume. This may be done by using expansion joints at each bent or at each alternate bent if the bents are close together. In case expansion joints are placed at a greater distance apart so that considerable movement takes place, it will be necessary to have expansion joints in the metal flume at these same points also.

(C) Preservatives

The best preservative for the iron sheets used in metal flumes is a galvanized coating. This effectually preserves the outside of the flume indefinitely. On the inside of the flume the galvanized coating, while not so permanent as on the outside, because it is subject to the erosive and corrosive action of the water carried in the flume, in most cases will last a long time. It may be further protected by coating the inside surface of the flume with paint from time to time.

There are several kinds of paint in use at the present time for this purpose and the ones giving the best service usually are those applied hot. The U. S. Reclamation Service uses a priming coat of water-gas tar and a second coat of coal-tar, both applied hot. Other kinds of coating which have given good service are biturine enamel and biturine flume and pipe coating. The protection of steel substructures for metal flumes is the same as for any steel structure exposed to the weather and is accomplished by either galvanizing or painting.

(D) Construction and Operating Difficulties

Some of the difficulties which have been encountered in connection with large-sized semi-circular metal flumes have been due principally to the flume taking the shape of a catenary under load instead of remaining in the semi-circular shape. This catenary shape changes as the load of water in the flume increases and causes the bottom of the flume to sag. Care must be taken in the design of the metal substructure to lay out the maximum expected sag in the flume sheet to allow the proper clearance to structural members of the substructure.

The catenary shape gives an angle to the direction of pull where the flume is supported at the top edge, throwing an eccentric loading on the girders. It also causes distortion at the ends of the flume where it is attached to the concrete headwalls and causes leakage at the beads on curves.

The eccentric loading on the girders may be taken care of by using cross-bars to support the weight of the flume or by designing the girders for the proper lateral stiffness. The distortion at the concrete connections may be taken care of by laying out the concrete collar (to which the ends of the metal flume are attached) in the shape of the catenary and the leakage at the deflections on curves also may be taken care of in the same manner.

Other difficulties encountered on extremely large-sized flumes are splicing the sheets so as to secure a water-tight joint and to secure the same rigidity at the splice to prevent unequal distortion of the head at the splice. This difficulty has been overcome by welding the splices to secure the necessary length sheet when that required is longer than may be secured in the market.

As leakage must be reduced to a minimum, utmost care must be used to check details of all joints so as to be sure that the designs contemplate the heads and loads.

Mechanics—Wood and Concrete

Under this heading is given the recommended features for wooden and concrete flumes and wooden and concrete substructures for the support of any type of flume. Wooden flumes made in rectangular and semi-circular types probably will be used as local conditions may dictate their economy or necessity, but the losses in water and annual costs usually will favor some more permanent installation.

For those cases where flues are to be installed the following conditions of design are suggested:

Wooden Flumes—Materials: Use yellow pine or sugar pine for lining. Harder woods do not last as well. Spruce and Oregon pine do not appear to last as well as a softer wood. The soft wood wets clear through while the harder woods are wet on the inside and dry on the outside. The swelling of the wet inside wood has a tendency to make it crack and break away from the dry outside with resulting disintegration and leakage. The lining using splines seems to last better and leak less than battens, but is not as convenient to replace.

The design of supporting structures for flumes should be based upon using accepted standards for working stresses in the kinds of timber available. Care should be taken to get stock as well seasoned as is practicable because checking and cracking will reduce strength. The supporting ties and girders are exposed to long periods of hot, dry weather and wet lumber will cause movement and splitting.

Use low crushing values. The use of pressure-creosoted lumber will tend to give better seasoned stock and also render it more immune to rot and insect attack. The annual cost should be checked over carefully to be sure that the extra epxense of creosoting at the time of initial installation will represent considerable saving over a period of years.

Concrete—Flumes made of concrete properly designed and made from well-proportioned and well-made concrete offer probably the best permanent installations, but the heavy original cost with frequent inaccessible locations for this type of construction often prohibits its use. The design will not be gone into in detail here, but the same conditions will apply as regards amounts and locations of reinforcing steel as apply on standard concrete construction. Expansion joints must be included and care must be taken in design to avoid leakage.

Examples of concrete supports for metal flumes are in use, but unless there are extenuating circumstances it would seem that this type of construction will prove too expensive or cumbersome.

Economics

This subject of course is one which is carefully analyzed in whatever type of construction is being considered and in this report the information gathered has been included in the foregoing subdivisions.

In general, however, the following points will need consideration:

The water cross-sectional area to be provided depends upon the volume to be carried and the velocity. The velocity, in turn, depends upon the grade and frictional resistance. For a long flume where the available grade will allow it is economical to make the water cross-sectional area small, using, within practical limits, as high a velocity as possible. For the short flumes it is more economical to allow the flume about the same water cross-sectional area as that of the canal upstream and downstream from it. Otherwise a disproportionate loss of head at the inlet transition will occur.

In any type of flume the form of waterway which gives a maximum velocity for a given cross-sectional area and grade is that wherein the hydraulic radius is greatest and the wetted perimeter least. This is the form having the most advantageous hydraulic elements for in it the least resistance is offered to the flow of the water. By the calculus it is shown that in any

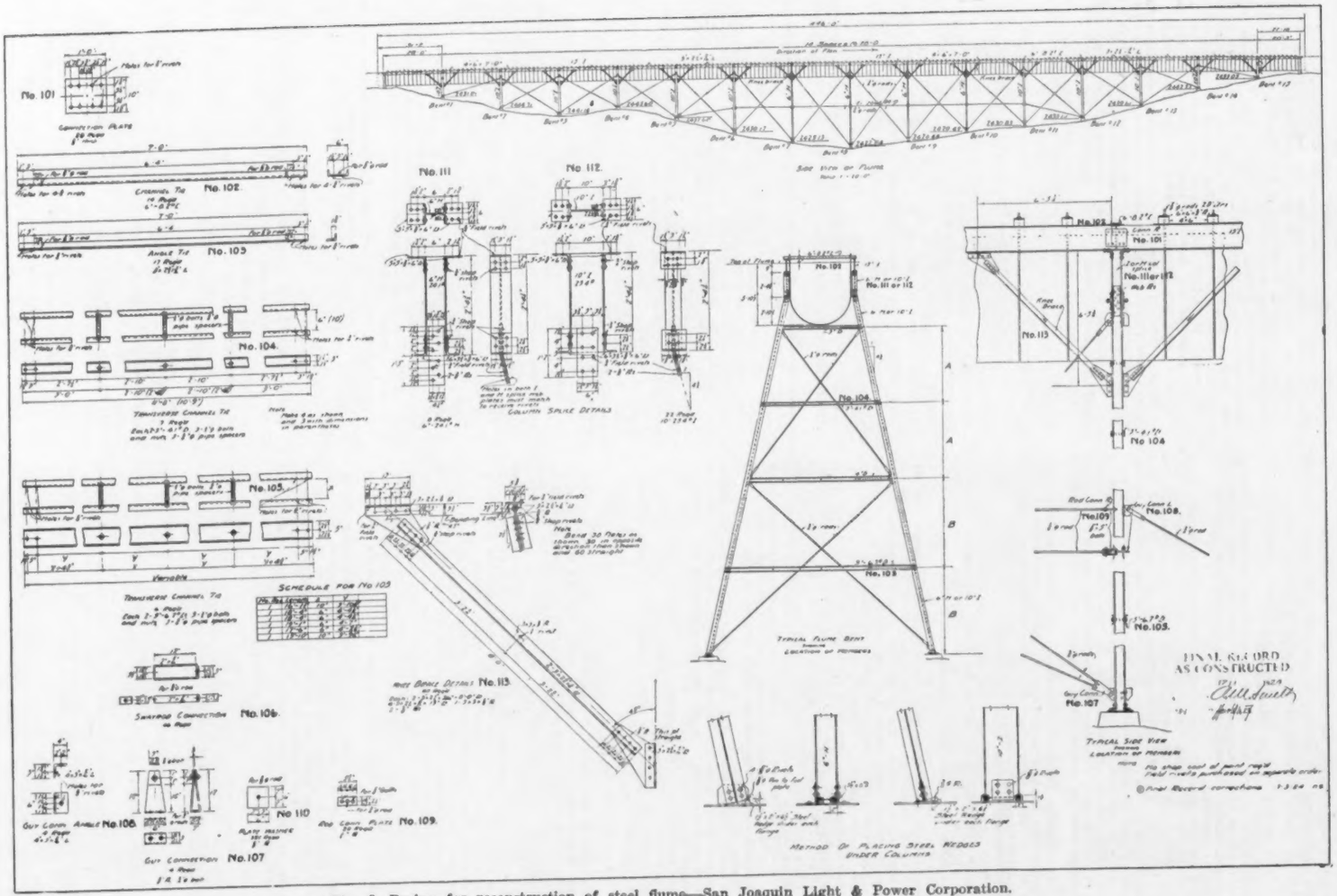


Fig. 9. Design for reconstruction of steel flume—San Joaquin Light & Power Corporation.

channel the most advantageous hydraulic elements obtain where

$$\text{hydraulic radius} = \frac{\text{depth of water}}{2}$$

and also where

$$\frac{\text{bed width}}{\text{depth of water}} = 2 \tan \frac{\phi}{2}$$

ϕ being the angle of side slope.

From the above considerations, then, for a rectangular box flume the best hydraulic elements and most economical water cross-sections obtain when the bed width is twice the water depth. While this principle commonly is followed in the design of flumes of rectangular cross-section, there are, however, other conditions which at times may make some other proportion more economical. For a bench flume a comparatively deeper and narrower section will require less excavation which on steep hillsides may decrease the total cost materially; and around the face of vertical cliffs where anchors must be used the cost of the flume will be decreased. Where it is desirable to keep the depth of water in the flume about the same as the depth of water in the canal, as is the case with short flumes, it may be necessary to vary the cross-section either way, making it shallower and wider or else deeper and narrower than the cross-section of best hydraulic elements.

For a given cross-sectional area the shape of flume cross-section having the least wetted perimeter, greatest hydraulic radius and consequently that with the most advantageous hydraulic elements effecting the greatest economy in use of materials in construction of the waterway itself, is the semi-circular. A semi-circular flume will convey far more water between two given points than will any other form of conduit wherein the same amount of materials is used.

In the following table is shown a comparison of cross-sections of the rectangular and semi-circular type, giving the best hydraulic elements and most economical form of water cross-section. In both cases the hydraulic radius is equal to one-half the depth, which in a semi-circular flume running full would mean that the hydraulic radius would equal ¼ of its diameter. All values are in terms of the water cross-sectional area A.

TABLE VIII—Comparison of cross-section.

	Rectangular	Semi-circular
Depth	$0.707\sqrt{A}$	$0.798\sqrt{A}$
Bottom width	$1.414\sqrt{A}$	
Width at water surface	$1.414\sqrt{A}$	$1.596\sqrt{A}$
Wetted perimeter	$2.828\sqrt{A}$	$1.773\sqrt{A}$
Hydraulic radius	$0.354\sqrt{A}$	$0.564\sqrt{A}$

Smoothness of Flume Lining—Having considered the size of flume as affected by its shape of cross-section, which should be governed largely by a consideration of its most advantageous hydraulic elements, the factor of relative smoothness is next to be considered for the various types of construction from a standpoint of economic design.

TABLE IX—Comparison in value of wetted perimeters for semi-circular metallic and rectangular wooden flumes.

	Semi-circular (Metal)	Rectangular Wooden	
Capacity (sec.-ft.)	600	600	
Length (ft.)	1,000	1,000	
Slope	1	1	
	3,000	3,000	
Value of "n"	0.012	0.015	
Water cross sectional area	101.8	128.0	(=8x16)
Wetted perimeter	25.4	32.0	
Hydraulic radius	4.0	4.0	
Velocity	5.9	4.7	

In the above comparison of two flumes used to carry the same amount of water on the same grade it may be noted that the wetted perimeter of the semi-circular metallic flume is 79.4 per cent of that of the wooden rectangular flume, or for the total length of 1,000 ft., 25,400 sq.ft. compared to 32,000 sq.ft.

The above illustrations bring out the fact that shape or form of cross-section, smoothness of waterway and grade of the flume bottom or water surface are factors vitally affecting the value of the wetted perimeter and this in turn to a large extent affects the economy of design and hence the best returns on the capital cost.

TABLE X—Effects of certain variations.

Effect of Value of "n" in Increasing Wetted Perimeter in Flumes of Rectangular Cross-Section

	n=0.012	n=0.014	n=0.016
Capacity (sec.-ft.)	600	600	600
Length (ft.)	1,000	1,000	1,000
Slope	1/3000	1/3000	1/3000
Water cross-sectional area	7.4x14.8=109.6	7.8x15.6=121.9	8.2x16.4=134.6
Wetted perimeter	29.6	31.2	32.8
Hydraulic radius	3.7	3.9	4.1
Velocity	5.5	4.9	4.45

The above computed wetted perimeters for the same capacity and grade but with varying values of "n" may be shown as follows:

"n"	Wetted Perimeter	%
0.012	29.6	90.2%
0.014	31.2	95.0%
0.016	32.8	100.0%

showing that for a change of one point in value of "n" there is a change of about 2.5% in the value of the wetted perimeter, in this particular case.

Effect of Change of Grade on Wetted Perimeter:

	Slope=1/3000	Slope=1/4000	Slope=1/5000
Capacity (sec.-ft.)	600	600	600
Length (ft.)	1,000	1,000	1,000
Value of "n"	0.014	0.014	0.014
Water cross-sectional area	7.8x15.6=121.9	8.15x16.3=133.0	8.6x17.2=148.0
Wetted perimeter	31.2	32.6	34.4
Hydraulic radius	3.9	4.1	4.3
Velocity	4.9	4.5	4.05

Hence, for a slight change in the value of the slope there is an appreciable variation in the wetted perimeter.

Full consideration must be given in all cases to the annual cost of the installation, using representative and available information as to life of the entire structure. Present appropriations should not be a deciding factor where over-all economy is worth anything.

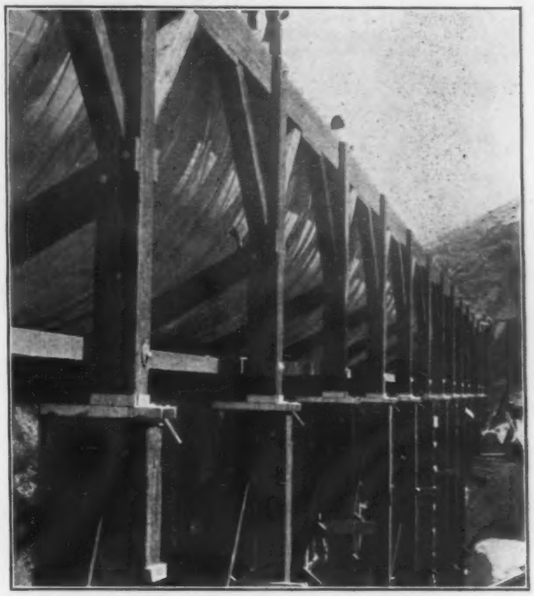


Fig. 10. Wooden substructure for Borel plant of Southern California Edison Company. Note channels at bearing points to reduce pressure.

Erection of Flumes

I. General Plant Layout.

(a) Labor Quarters.

Flumes generally located in remote regions where it is necessary to provide quarters for the men. Temporary quarters consisting of tents or rough frame buildings are all that are necessary.

(b) Office and Shop Buildings.

Office and shop buildings are not necessary on the small flume job. On large jobs a tent or rough frame building provides space for foreman, time-keeper and small commissary. A shop is not necessary except when work is carried on under bad weather conditions. Generally all that is required is a portable blacksmith shop for sharpening steel and doing general blacksmith work.

(c) Working Plants and Equipment.

Flume jobs usually are too small for extensive plant for fabrication or erection of flumes.

Equipment required usually consists of portable compressor, small concrete mixer, circular cut-off and rip saws—power operated, small hoists, small derricks, trucks and tractors, and industrial railways

II. Receipt and Storage of Materials.

Materials are all checked at rail head and are hauled by truck to flume site, where storage yard is made if necessary for sorting and segregating such material as steel and wooden flume supports, metal flume sheets and lumber. Generally all material is stored as near the flume site as possible and distributed on the initial delivery as much as nature of the terrain will permit. Cement is stored in existing buildings, in tents or in the open covered with canvas.

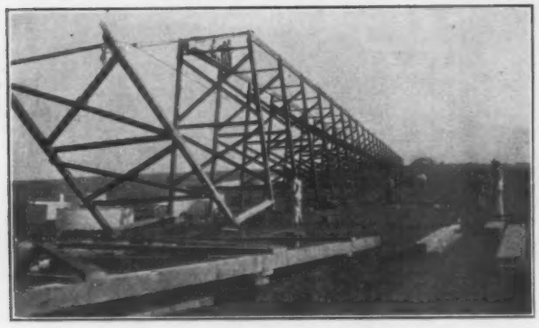


Fig. 11. Erection of bents, Merced Irrigation District.

III. Excavation.

Flume work reported has consisted practically entirely of the replacement of old wooden flumes and siphons with metal or concrete flumes on the same location so there has been little excavation required. This excavation consisted of slight changes in grade and alignment and the excavation for piers and bent footings. This has been practically all done by hand with only a small amount of team work. New work with heavy excavation would be handled with standard excavating machinery adapted for such work, such as steam or gasoline shovels, drag line scrapers, etc.

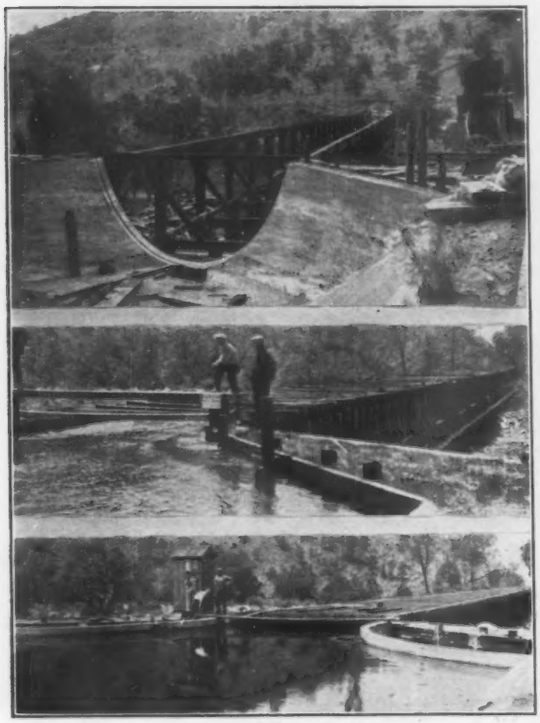


Fig. 12. (Above) Borel flume outlet. (Center) Inlet on Borel flume. (Lower) Same outlet as center after replacing wooden flume with metal flume. Note comparison of water surfaces.

IV. Material Distribution Along Flume.

Where roads exist, materials are delivered along the flume on the initial delivery, otherwise materials are hauled by truck as far as roads permit and then are distributed by other means. On one conduit about six miles long made up mainly of tunnels connected by short sections of wooden flume where no means of access except a narrow trail existed, the flume materials were delivered by truck to both ends and then were distributed with small trailer wagons on 14-in. wheels with a

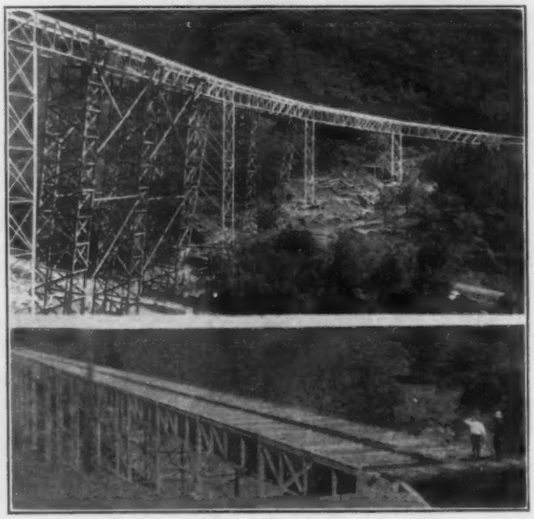


Fig. 14. Santa Ana No. 3 conduit, Southern California Edison Company (above) and Borel conduit (below).

capacity of 2,000 lb., hauled by small cut-down gasoline tractors operating through the tunnels and the wooden flumes before the latter were dismantled. On this same job gravel for concrete footings and transitions from flume to tunnel was hoisted at two points from the river bed 200 to 400 ft. below the flume bench, using cableways operated by small gasoline driven hoists. Considerable material also was packed by mules and burrows on this job due to the necessity of getting as much work as possible done before turing the water out of the flume and in order to cut the shutdown of the power plant to as short a time as possible. The tractors worked out very satisfactorily for hauling through the tunnels and the job was completed in scheduled time.

On another job in similar country where there was not sufficient room for truck operation, a small tractor was used to haul material along the flume bench on an orchard wagon or sled. On a portion of this job a cableway about 500 ft. long operated by gasoline hoist was used to hoist all materials to the flume bench from which point distribution was made similarly to above.

On another job the bottom of the canal on which the flume under reconstruction was located was used as a roadway for delivery of materials.

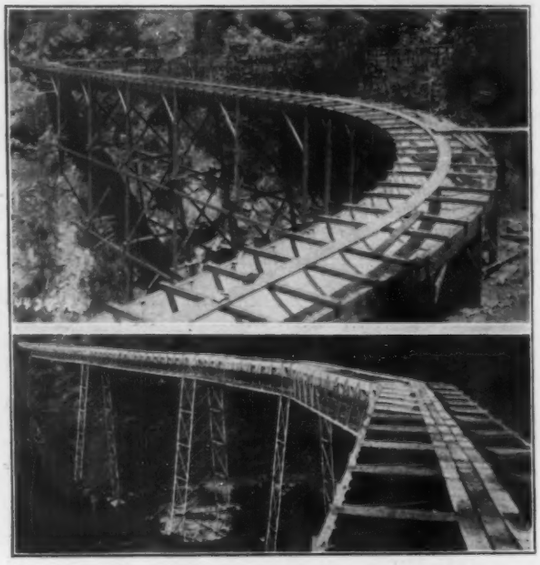


Fig. 15. Butte Creek conduit of Pacific Gas and Electric Company (above) and Santa Ana No. 3 conduit, Southern California Edison Company (below).

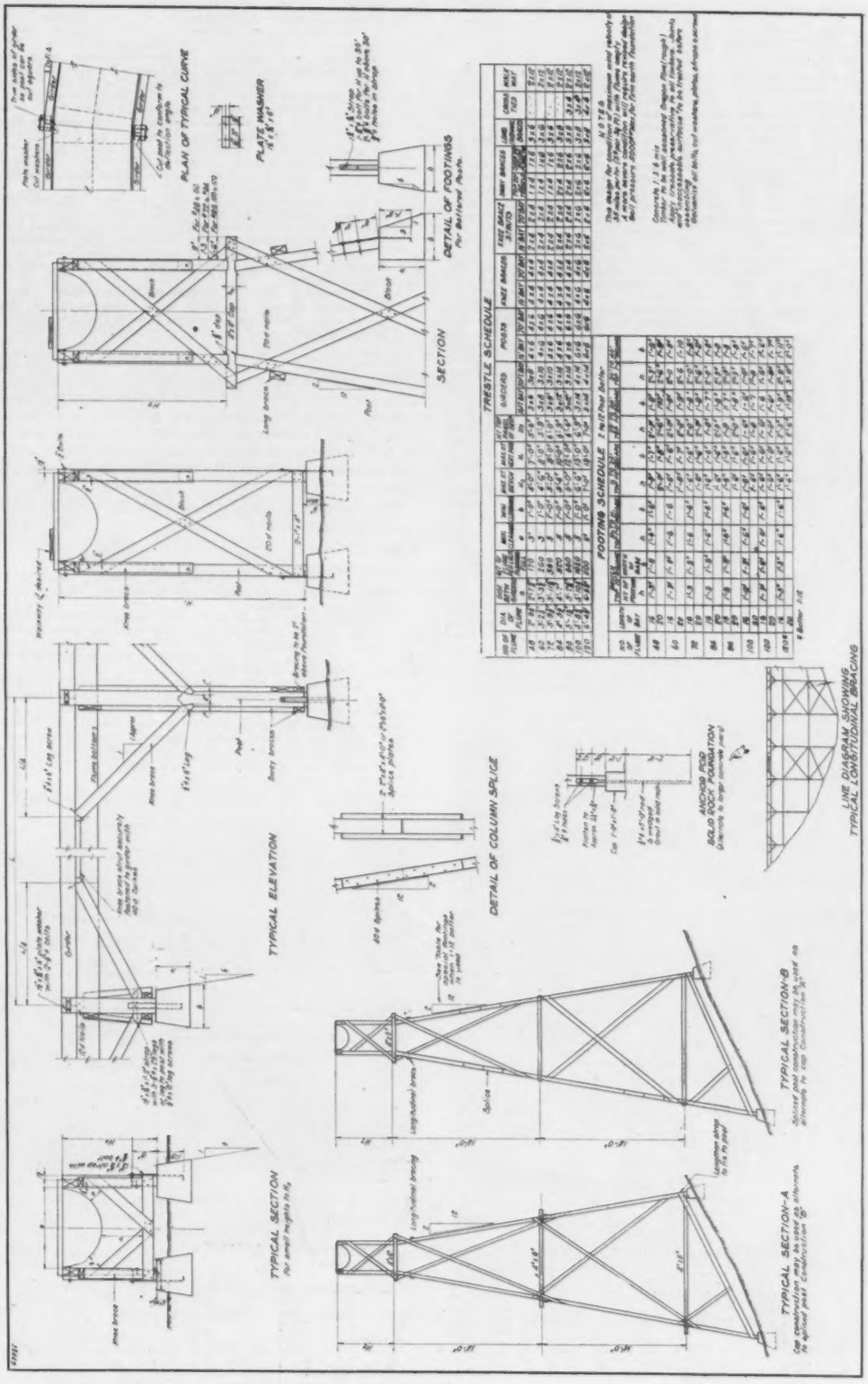


Fig. 13. Timber trestles for semi-circular metal flumes. Wind load 5 lb. per sq. ft.

Where the construction of a truck road along the flume is too expensive, materials can be delivered to certain accessible points from which distribution can be made on light railway constructed on top of the flume trestle, as same is built both ways from these accessible points.

V. Material Erection.

(a) Wooden Flumes.

No recent experience reported.

(b) Metal Flumes.

(All on side-hill bench or on trestle crossing canyons and creeks.) Concrete for footings usually mixed by small mixer, gasoline driven. On the smaller-sized flumes on a side-hill bench the supporting steel structure was low and erection was simple, being entirely by hand. For hoisting the heavy longitudinal girdiers block-and-tackle were used supported by a steel extension bolted to the top of the bent legs.

For the larger flumes this same method was used except that it was necessary to use a small portable hand operated derrick supported on top of the completed steel or wooden substructure to hoist and place the flume sheets which were too heavy and unwieldy to handle otherwise. A steel spreader bar of flume width and with clamps on each end for attaching to the tops of the sheets was used for lifting them and keeping the sides spread out to correct gage.

For flumes carried across gullies and canyons on wooden trestles the construction of the trestles was similar to ordinary heavy wooden trestle construction. A small derrick was moved along the top of the finished structure for placing the heavy timbers. For flumes carried on high steel trestles the trestle usually consisted of towers carrying trusses from 40 to 100 ft. in length. In these cases the towers were erected with floating gin-pole similar to transmission tower erection. The trusses then were erected on light false work constructed between the towers. Erection of the flume sheets then was the same as for the lower flumes.

On long tangents of metal flume it was found that generally the sheets would gain on one side or the other to such an extent that it was necessary to have special-shaped sections rolled at the factory and shipped to the job by express to correct this creepage, and bring the joints back again at right-angles to the flume center-line.

On a 348-in. metal flume erected by the Southern California Edison Company a riveted longitudinal joint in the flume sheets was located about one-third of the distance down from the top of the flume. This riveted joint was located at a point where the sheets were nearly straight and with flume only part full the slight eccentricity of the riveted joint caused the sheet to bow in and force the half-round inside rod out of the joint groove, thereby relieving its pressure in holding the sheets tight together at the joint. It was necessary to jack these half-round bars back into the grooves and to force them beyond their regular curvature in order to give them a premanent set outward. In some cases it was necessary to hold these half-round rods in place with U-bolts through the sheets. This condition has been remedied on later large flumes by keeping this longitudinal joint away from this nearly straight section of the side of the flume, and by making this a welded joints.

(c) Concrete Flumes, Precast and Built in Place.

Concrete flumes reported all were built in place. These were short and erection was simple. Forms were built in place and concrete for floor and side walls was wheeled on runways supported on top of the forms. Mixing of concrete was done at one end of the flume.

VI. Painting and Waterproofing.

Painting by the Southern Cauifornia Edison Company of the inside of metal flumes all has been done by hand. Treatment consists in removing the grease of galvanizing with a solution composed of the following ingredients: 2 oz. chloride of copper, 2 oz. nitrate of copper, 2 oz. sal ammoniac, dissolved in 1 gal. of warm water with 2 oz. commercial hydrochloric acid. (Use glass or earthen vessel.)

This solution is brushed on the inside of the flume, let stand for 12 hours and then brushed off clean. After cleaning flume as above and removing all loose scale one coat of water-gas tar followed by two coats of coal-gas tar are applied with brush. These coats are applied with the temperature of air and metal above 60 deg. F. Water-gas tar is specified to have a specific gravity between 104 and 110 at 60 deg. F. and to be of such consistency that it can be applied with a brush. The water-gas tar is applied cold and the first coat of coal-gas tar is applied hot a few hours later and brushed out as thin as possible so that it will not run or peel after it is dry. The second coat of coal-gas tar is applied after the first coat is completely set.

The practice of the Pacific Gas and Electric Co. is not to paint metal flumes when first installed, due to difficulty in making the paint adhere to the freshly galvanized surface, but to delay until the summer following the installation of the flume. Then two coats of asphaltic compound are applied. Experiments still are being made as to the best type of coating to be used.

On wooden flume substructures the practice of the Southern California Edison Company is to use creosoted lumber and paint with creosote all ends of timbers and contact points between timbers.

Maintenance

The matter of maintenance of course plays a most important part in the life of flumes and the design and erection must be followed by years of continued operation. The practice of regular inspection and keeping up of wearing and corroding parts will naturally be represented in longer life and less loss entailed by shutdowns.

The following schedule represents current practice by member companies:

I. Metal Flumes.

(a) Coatings.

Outside—Required in design to include galvanized materials. This coating to be heavy and be made as nearly 100 per cent cover as is possible.

Inside to resist abrasion and water—When galvanized surfaces have been treated to receive paint a heavy coating with a rubber-like hardness with resilience which will prove resistant to wear if water and abrasives in water should be applied.

(b) Replacement of sheets.

Spare sheets, rods, washers, etc., should be kept at convenient places along flume line to be available to replace breaks from any cause.

(c) Adjustment of flume.

Rods should be adjusted from time to time to take care of uneven settlement which may result in leaky joints and oakum, tar, and caulking tools should be included in equipment for repair.

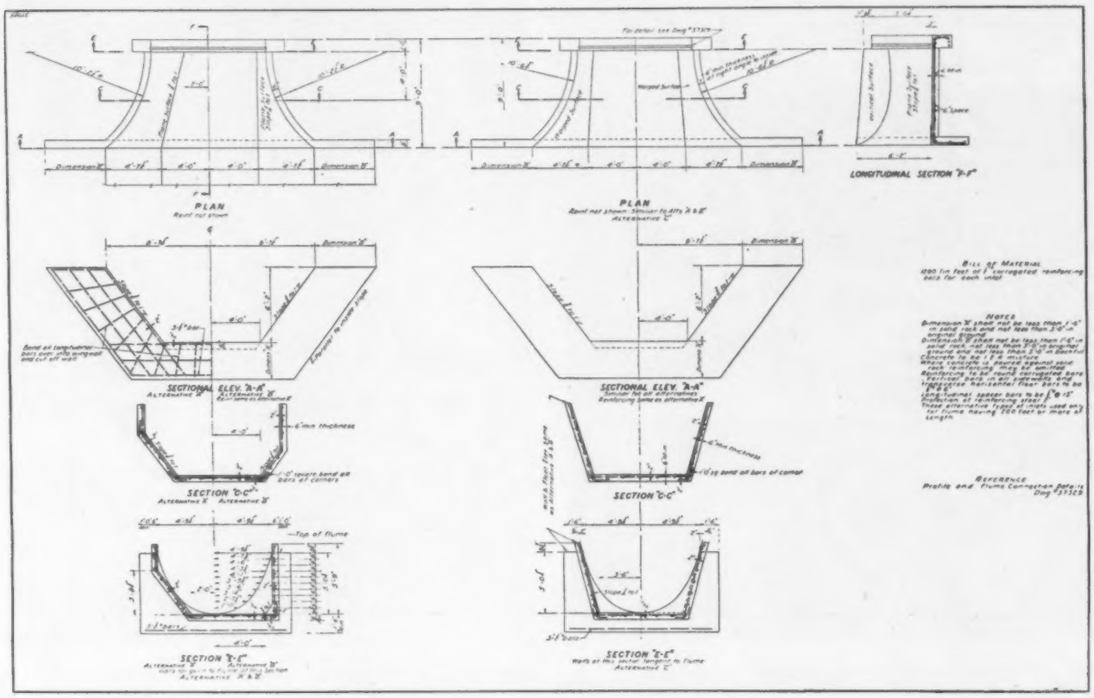


Fig. 16. Alternate types of inlet structures for metal flumes.

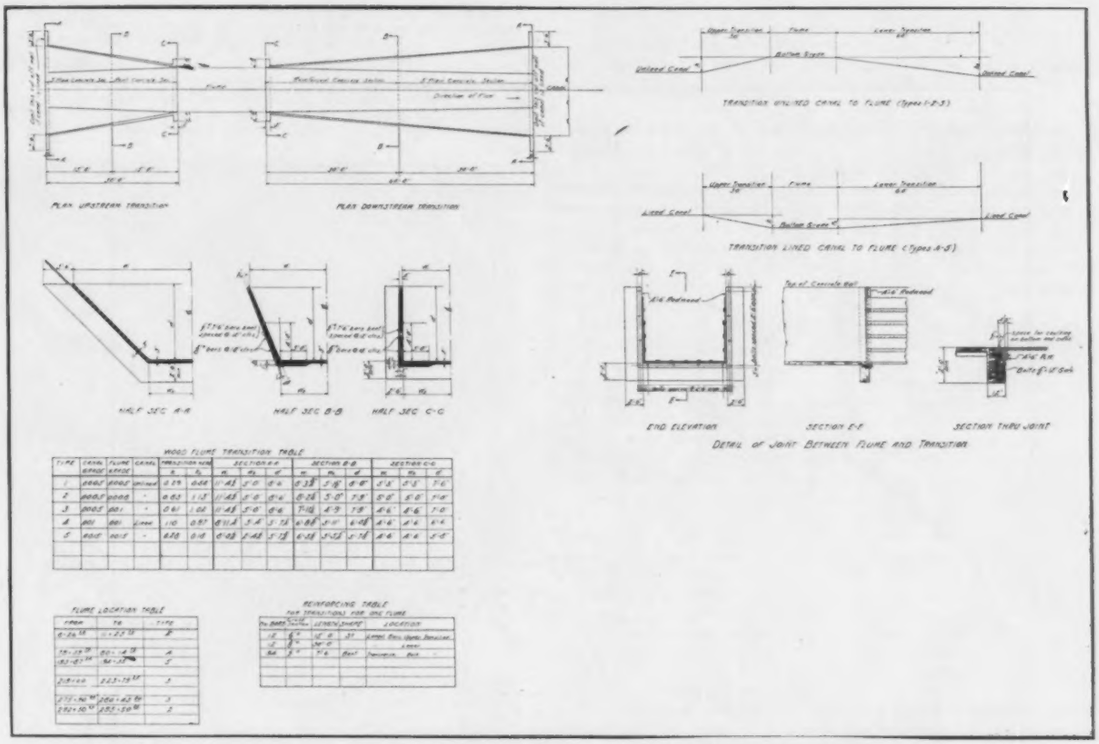


Fig. 17. Transitions for wooden flumes on American River development of Pacific Gas and Electric Company.

II. Maintenance of Substructures.

section of the side of the flume, and by making this a welder

(a) Steel.

If galvanized and erected with galvanized bolts there is little need for repair. Inspection as to settlement or distortion is all that is necessary. If made from black steel, painted, it will be necessary to watch for corrosion and keep intersections properly coated.

Fig. 18. Distribution of materials with tractor, Merced Irrigation District (above). Framing wooden substructure, drilling by air, Merced Irrigation District (below).

(b) Wood Structures.

There should be a practice to use creosote or carbolineum or other creosote compound as a dip or paint for application to ends of all timbers and contacts between timbers on our metal flume trestles.

In some cases where a flume is on sliding ground frequent replacements of cross-bracing will be necessary.

It has been found necessary in a number of instances to jack up the flume bents and place blocks between concrete footings and posts. This is easily done as an empty flume is not heavy. The flume is flexible and no leaks will occur if the flume is raised as much as a foot at a time.

In some cases in shifting ground any material change in

Fig. 19. Nevada Irrigation District compressor plant for painting (above). Painting interior of Borel metal flume (center). Upper Hanover Water Users' Association creosote dipping plant for treating flume timbers (below).

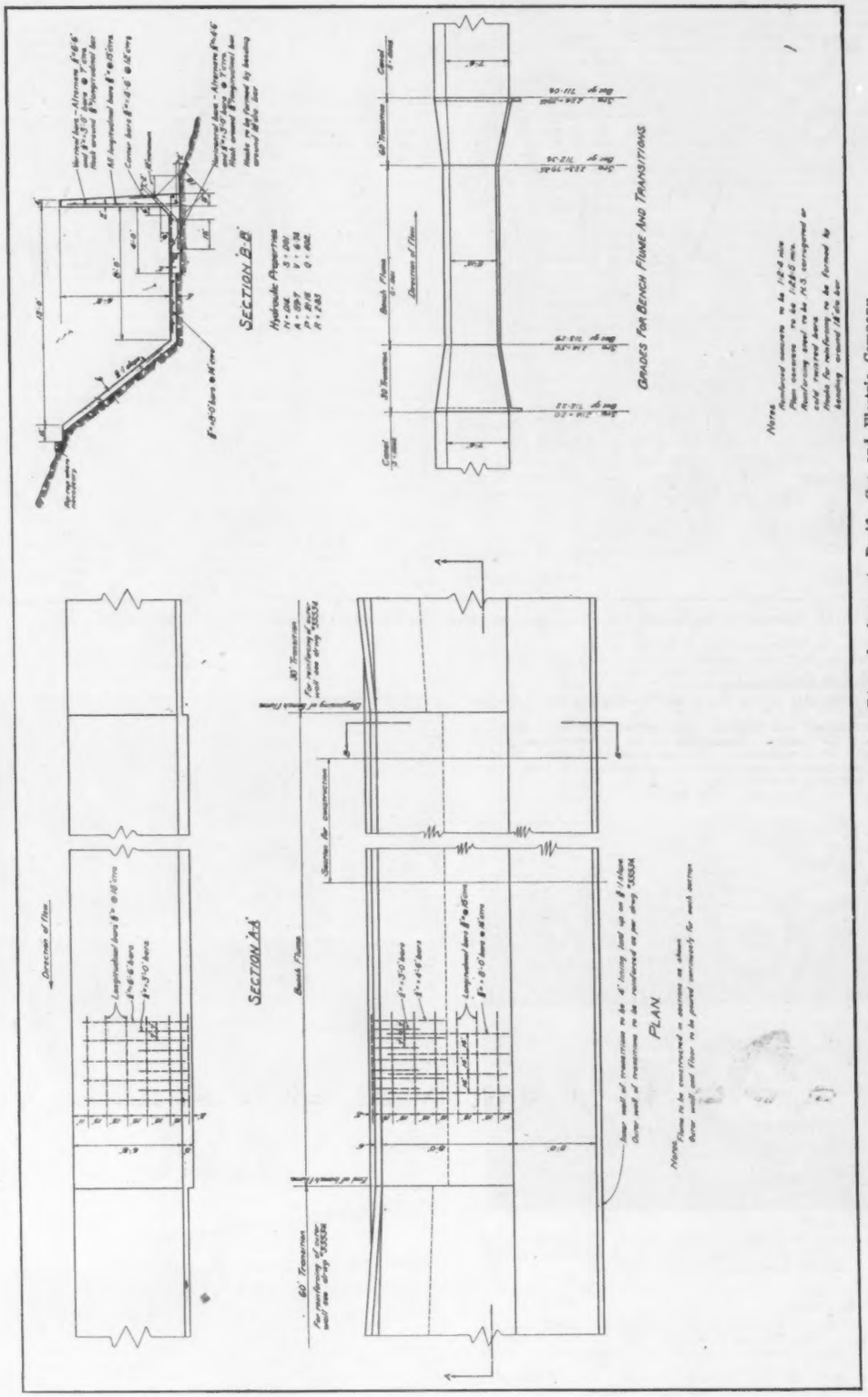


Fig. 20. Reinforced concrete bench flume—American River development, Pacific Gas and Electric Company.

slope of ground at flume footings results in slides from above so the flume is set on a temporary concrete or wood footing and raised as occasion may demand.

III. Footings.

It is necessary to inspect and clean around footings as often as twice a year on flumes on steep hill sides with loose rock and earth present. The most difficult problem in connection with flume maintenance has been that of protecting a flume against rocks and slides. Try to keep the loose rocks above the flume from rolling against flume. Install wye-shaped chutes and buffer posts to protect bents.

The moving rocks and slides appear to be the only cause of breaks in metal flumes against which it is very difficult to provide ample protection.

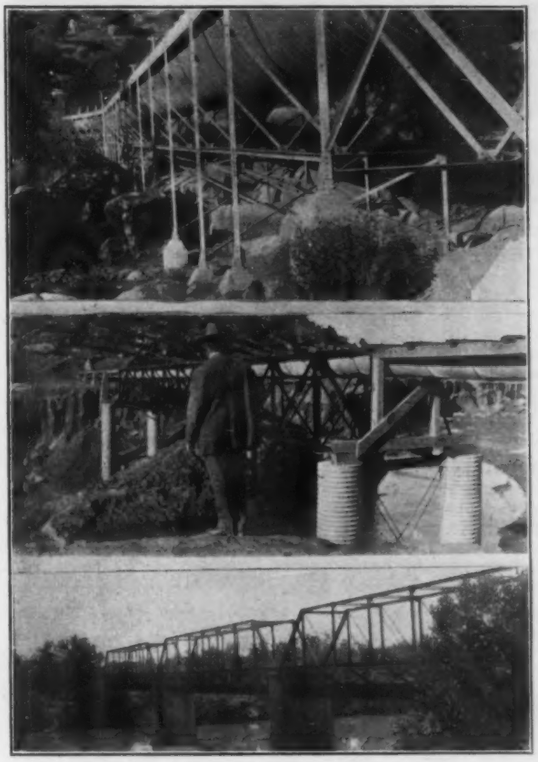


Fig. 21. Headworks flume of Southern California Edison Company Kern River No. 1 plant (above). (Center) U. S. R. S. Gunado flume, Arizona. (Below) Anderson Cottonwood Irrigation District truss across Sacramento River.

Maintenance of Wood Flumes—Lining and Belting

Lining usually is of yellow pine or sugar pine both of which have proved satisfactory. The life varies materially, depending upon whether the boards are continuously wet or alternately wet and dry. Where water is maintained at a uniform depth the linings may last as long as 25 years, while with flumes with the boards alternately wet and dry usually they last about 10 years depending upon exposure to sun and other weather conditions.

The belt posts on the flume seem to rot first and require replacement. Then the ends begin breaking off the sills and then the caps begin to break. The replacement of complete belts usually is made with water in the flume by placing new belts between the weak ones. Replacement of posts except for posts at box joints usually can be made without turning out the water.

Stringers usually last about as long as the lining. Their replacement where the lumber has been defective is made with water out of the flume. The bent structures usually begin to decay at the bottoms of posts where moisture and soil contact frequently occur. These can be replaced readily with water in the the canal. It is preferable to use spruce or Oregon pine for the substructure and flume belts as it is stronger, lasts longer and any weakening of timber usually is readily noticeable by a decided bend before failure, while yellow pine has a tendency to snap without warning or bowing. Cedar seems to be the best wood for footings due to its long life in contact with the soil.

The wooden flumes on hillsides have a tendency to settlement so that it is desirable every year or two to go over flumes and raise them to uniform grade to maintain the full flume capacity. The wooden flume is subject to considerable leakage especially when alternately wet and dry. It is necessary whenever the depth of water changes materially to caulk the box joints and board joints with oakum. In cases of flumes with constantly varying head it may be necessary to keep a crew constantly caulking, but under the usual condition of a fairly constant summer head the ditch agent can take care of caulking leaks on his particular beat.

The question of the prevention of slides and rocks breaking the flumes is one of constant attention, as all steep mountain-side flumes are in constant danger from

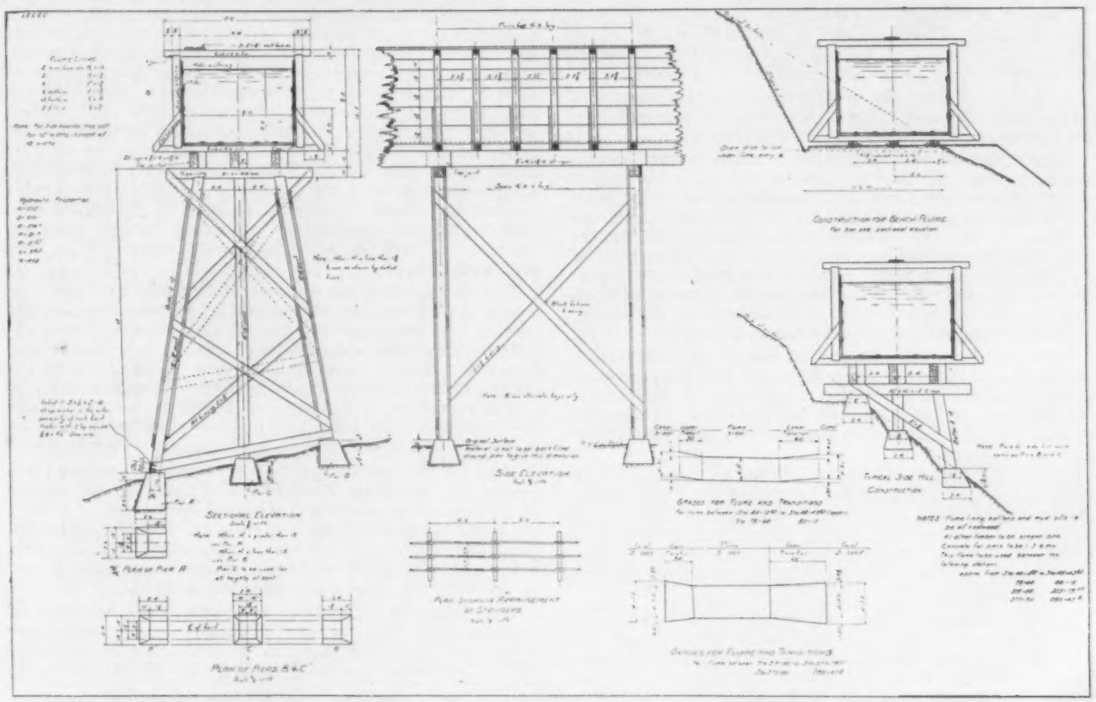


Fig. 22. A flume having a grade of 1 ft. per 1,000—American River development, Pacific Gas and Electric Company.

TABLE XI—Patrol and routine flume maintenance.

Name of Plant	Capacity Sec.-Ft.	Conduit Length, Mi.	Wood Flume, Ft.	Steel Flume, Ft.	Concrete Flume, Ft.	Number Men	Interval of Patrol, Days
Borel	560	11.20	2,666	2,314	212	5	{Wood 1 {Steel 3½
Kaweah No. 1	25	5.80	30,000	0	0	2	½
Kaweah No. 2	58	3.17	4,540	0	0	1	½
Kaweah No. 3	76	4.75	0	0	19,000	2	½
Kern River No. 1	393	8.20	1,179	856	114	1	7
Kern River No. 3	600	12.90	0	0	3,338	1	30
Santa Ana River No. 1	70	2.82	0	2,240	400	1	7
Santa Ana River No. 3	76	2.70	0	5,087	0	1	7
Tule	37	6.82	23,513	0	228	2	½

rocks and slides. It might pay to sluice out many of the known dangerous slides providing they do not cut back so far as to result in further danger from larger slides. Remove known menacing large rocks, but keep a supply of lumber on hand at convenient points to replace from 4 to 20 16-ft. boxes of flume, depending upon location and length of flume to be maintained. An unusually wet winter or heavy rains after a long dry period usually starts some action among the rocks and earth on the mountain sides above the flumes. Frequently build a roof on top of the flumes to let material slide over where slides of long standing exist. Provide buffer posts and wye-shaped chutes to deflect rocks between bents. Sometimes it is possible to bridge the worst sections by trussed spans.

In building flumes on steep hillsides it appears to be a desirable plan to avoid cutting into the hill (benching) as the ground stands at about its maximum natural slope and benching starts slides which fill in around footings and bent posts and in some cases around the flume lining resulting in annual expense for clearing footings and short life to flume structure due to contact of flume with earth.

The headings of flumes may begin to leak in about 4 or 5 years and need replacement on an average of twice per flume life. It is very desirable that wooden flumes all have concrete headings. Using concrete headings will reduce flume leakage materially as most of the water escaping from flumes is at the headings.

The replacement of the wooden flume then becomes easier as the excavation and backfill for headings is omitted. The flume erector can start the replacement of box work from the existing concrete header. The grade of flume can be readily obtained if concrete headers are in place.

There is a division of opinion as to the use of creosoted timber. There seems to be considerable of an advantage in favor of pressure creosoting the timber, but experience and expense should be considered.

As a typical example of the maintenance crews and patrol intervals used, Table XI shows the practice of the Southern California Edison Company.

Regular patrol and inspection is made a part of station routine at all plants operating flumes. Local conditions, size, length, age and accessibility of the flumes govern the frequency of inspection and number of men required. Usually the headworks tender divides the work with the patrolmen and covers the upper part of the line. These men are expected to locate and repair minor leaks, dirt and rock slides, minor damage to footings or substructure and to promptly report difficulties which they cannot repair without assistance.

Table XI lists the flumes operated by the Edison Company and indicates the number of men employed on routine maintenance and the frequency of inspection. The number of men stated includes the headworks tenders. In some cases only a part of one man's time is spent on flumes.

Periodical inspections are made by the station chief and division superintendent who decide upon any major repairs and send in the flume maintenance crew to do the work. In case of special heavy substructures a careful inspection of every timber is made once a year and a heavy construction gang is organized to replace those found defective.

Growth of green algae has proved troublesome in some cases and fairly good results in removing it has been obtained by floating brush through the flumes. Mineral deposits from the water accumulate in some flumes to such an extent as to interfere with the flow. Such deposits have been removed partially by scraping the sides and bottom of the box. Both of these things continue to be the source of some trouble.

Concrete Flumes

Concrete flumes frequently are damaged by freezing and erosion where soft concrete may have been placed. The caddis worm (larva of the caddis fly) will cling to the sides of flumes and builds around itself a shell. This growth will cause some reduction in the flow and will need to be scraped off. Leaks at expansion joints will develop and need considerable attention.

References to Flume Experience by Agencies Outside of P. C. E. A.

Attention is directed to the records of the U. S. Reclamation Service whose scope covers all types of flume construction. The details and experience are available in the publications of the department and will prove invaluable.

The American Society of Civil Engineers also furnishes valuable information which can be used for reference.

Prevention of Silt Deposits in Conduits*

The use of "sand-traps" and settling basins to remove debris from conduits has been wide and varied. Their development has been made largely on irrigation systems and most text books on irrigation engineering contain examples and brief description of this type of structure. The necessity of their construction, the economic factors involved and the theoretical factors governing the dimensions and layout usually are but briefly touched on.

The factors which must be considered in locating and determining the functions of settlers on irrigation systems and on hydro-electric developments by no means are the same. The desirability of maintaining silt for fertilization in irrigation water may limit the amount of settling, whereas in a power conduit, the same silt might be the cause of excessive wear in the waterwheels. The larger debris is excluded principally because of the reduction of conduit capacity brought about by its deposition. This is true for both irrigation and power systems, but the larger debris is a greater menace to the power conduit because of its higher load factor and the difficulty of obtaining outage time for its removal, and the attendant heavy wear in pipe lines and waterwheels.

The debris-carrying characteristics of streams on which earlier developments have been located are known and the necessity for settling basins, if not anticipated, is understood at least after much trouble and expense. Where new streams are to be developed a study of the stream characteristic by water samples and observation of stream-bed debris movement should be undertaken so that settling structures may be planned or provided for in a comprehensive manner.

Most of the second part of this report has been obtained by digesting Professional Paper No. 86 of the U. S. Geological Survey, "The Transportation of Debris by Running Water" by Grove Karl Gilbert. The information contained therein is rather general in character and is reproduced here to throw what light it can on an otherwise generally slighted subject.

The data for preparing the curves for velocity of settlement in still water for quartz and galena particles, and for ideal lengths of settlers was obtained from "Textbook on Ore Dressing" by R. H. Richards.

* Report of subcommittee of hydraulic power committee—C. de Witt, chairman. J. E. White.

It is apparent that the ideal length of settler obtained by vectorially combining the velocity of settlement in still water with the velocity of flow never will be quite correct in practice. Due to eddy currents a length greater than this ideal length will be required. Experiments on the Kern River No. 3 settler of the Southern California Edison Company made in May, 1927, give valuable information on the possible error in a practical case.

The larger debris moved by saltation or traction may be excluded largely by a well-designed headworks provided with sluice channels to remove debris accumulations. If the stream is known to move great quantities of large debris during heavy run off it is conservative to provide additional means for removing this debris in the form of a settler. The debris capacity of such a settler should be governed by economic factors such as the value of head lost by the water in passing through, frequence of sluicing in connection with loss of water or outage of conduit, and topographical considerations. The larger debris may be trapped by a depressed bottom with only a limited reduction in velocity if the finer debris is not to be considered.

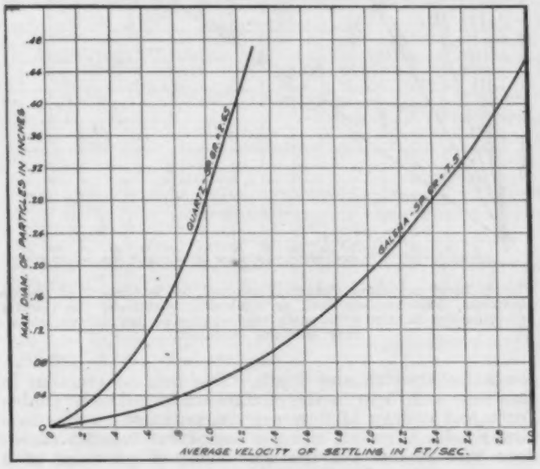


Fig. 1. Average velocity of settlement of particles in still water. Particles up to 0.4-in. maximum diameter. Data from Richards' "Ore Dressing".

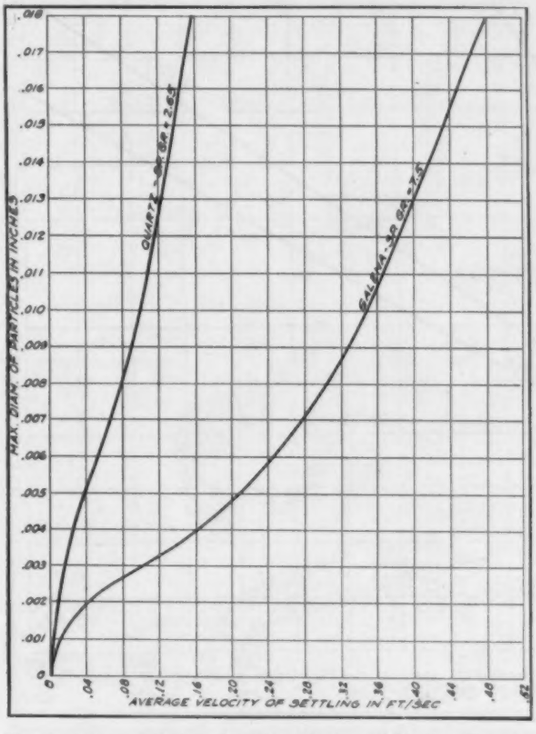


Fig. 2. Average velocity of settlement of particles in still water. Particles up to 0.019-in. maximum diameter. Data from Richards' "Ore Dressing".

The finer debris, carried in suspension presents a more complex problem. The necessity for making an economic study is much more pronounced in this case. In the case of coarse debris 100 per cent exclusion should be obtained, but in the case of suspended debris the cost of practically complete settlement would be prohibitive. An economic balance should be obtained between the cost of settlement for a given minimum size of debris and the capitalized cost of conduit cleaning, pipe and waterwheel replacement and plant outage. These factors must be determined by judgment and experience. When this economic balance is reached, the minimum size of debris to be settled out is determined. The presence of a forebay at the lower end of the conduit may have considerable influence upon the problem.

Another economic factor which must be considered in connection with waterwheel replacement is the gradual reduction in efficiency due to the enlargement of clearance from the cutting action. In one station in the Pacific Northwest the silt action is so marked that the cooling water of the transformers and bearings must be supplied by wells instead of the usual method of tapping the penstock. Another difficulty reported in this section is the settling of fine silt in the cylinders of hydraulic valves adjacent to the turbines although there is no circulation of water in the piping to these valves.

It is not the intention of this report to do more than point out these governing considerations of economical design. Subsequent sections will deal with the theory of transportation of debris by water and the details of layout and design. Once the minimum size of debris to be settled out is determined, the design of the settler becomes an engineering problem in which the various factors such as velocity, time of settlement, size, shape and length may be solved intelligently.

Transportation of Debris by Flowing Water

Flowing water transports debris in two general methods. One method is to sweep the material along the bottom by rolling or swirling the particles in a succession of leaps and is known as "saltation" or traction. The other method is to carry the material along bodily in suspension and the process is known as "suspension."

Discrimination between these two methods is sometimes very difficult to make where the velocity of flow is high. In some cases the "zone of saltation" may increase until it occupies the full depth of flow. Further increase of flow will make the cloud of particles denser until a flowing mixture of debris and water is almost reached.

Traction—The ability of a body of water to carry debris is known as capacity and is divided into a capacity for traction and a capacity for suspension which have a certain inter-relation.

The capacity for traction varies with the fineness and specific gravity of the debris, width and depth of water channel, and velocity and roughness of bed. The capacity of a stream may be expressed in terms of lb. or grams per sec. of load carried. The bed velocity which is just able to move debris of a given shape, size and specific gravity is known as the "competent" bed velocity. The mean velocity corresponding to competent bed velocity has been expressed in the following equation:

$$V_m = \frac{3.2}{\sqrt[r]{0.33}} \text{ where}$$

F is the mass of the particle.

This equation is based upon the assumption made by Hopkins in 1844 that the moving force of a current as measured by the volume or weight of material which it is capable of moving varies as the sixth power of the velocity. A later authority, Deacon, in 1883 reduced the proportion to the fifth power of the velocity.

Early investigators proved that the largest particle which a current can move is proportional to the square of the velocity. The table following gives the results of some early experiments which, however, did not give the dimensions of the transported particles.

Traction in a Natural Channel

Several formulas for expressing the relation between size of particle and velocity of flow follow:

$$D = \frac{0.059}{G-1} V^3, \qquad D = \frac{0.0042}{G-1} V^{2.7}$$

Where D = diameter of particle
V = mean velocity
G = specific gravity of particle

The capacity for traction observed in experiments with limited grades of material are less than for equivalent grades with greater diversity in fineness. The advantage gained is that the finer particles fill the voids between the coarser particles in the bed and thus a smoother bed of travel is obtained. It is noted that for a rough channel when fine material is added to a previously homogeneous material not only is the total capacity increased, but the capacity for the coarser part of the load is increased. The capacity of course is greater for fine debris than coarse and the lower the specific gravity the greater the carrying power. A flume or smooth bed gives a stream greater capacity than a natural channel. In a comparatively smooth channel, however, the path of rolling particles is roughened by the persence of smaller particles.

The capacity for traction in a semi-circular trough is only one-half as great as for a rectangular one of the same breadth and depth. The field of traction in this case is 1/5 to ½ the surface width. The available force and energy of flow are concentrated on the narrower field, however, and the competent velocity therefore will be less for the movement of particles of a given size than for the rectangular channel.

TABLE I—Traction.

In a Natural Channel.

Material	Competent Bed Velocity Ft. per Sec.
Brick clay, mixed with water and then allowed to settle	0.25
Fresh-water sand	0.67
Sea sand	1.10
Pebbles, pea size	2.00

In a Smooth Channel.

Material	Competent Bed Velocity Ft. Per Sec. Min.	Max.
Potters clay	0.27	0.35
Course angular sand	0.70	1.10
River gravel:		
Size of anise seed	0.35	0.53
Size of peas	0.62	0.70
Size of common beans	1.10	1.55
Round pebbles, 1 inch in diameter	2.10	3.20
Angular flints, size of hen's eggs	3.20	4.00

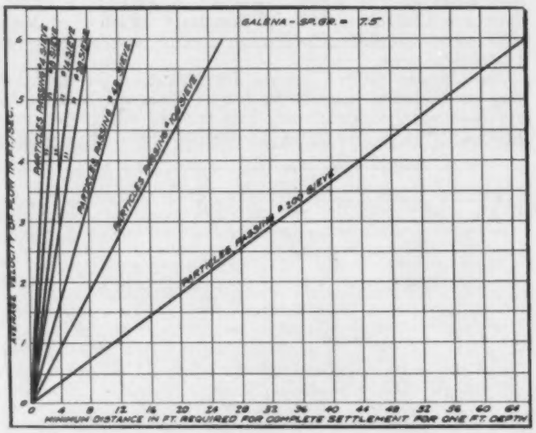

GALENA - SP. GR. = 7.5
PARTICLES PASSING #4 SIEVE
PARTICLES PASSING #8 SIEVE
PARTICLES PASSING #14 SIEVE
PARTICLES PASSING #28 SIEVE
PARTICLES PASSING #48 SIEVE
PARTICLES PASSING #100 SIEVE
PARTICLES PASSING #200 SIEVE
AVERAGE VELOCITY OF FLOW IN FT./SEC.
MINIMUM DISTANCE IN FT. REQUIRED FOR COMPLETE SETTLEMENT FOR ONE FT. DEPTH

Fig. 4. Ideal minimum distances required for settlement of galena particles. Distances obtained by combining vectorially the velocity of settlement in still water with the velocity of flow in the settler, eddy currents neglected.

Suspension—The process of suspension depends upon the diversity in direction of the strands of the current. If the lines of flow were exactly parallel to the stream bed there would be no suspension beyond the time required for settlement in still water. In the swirling movements which characterize the flow of streams

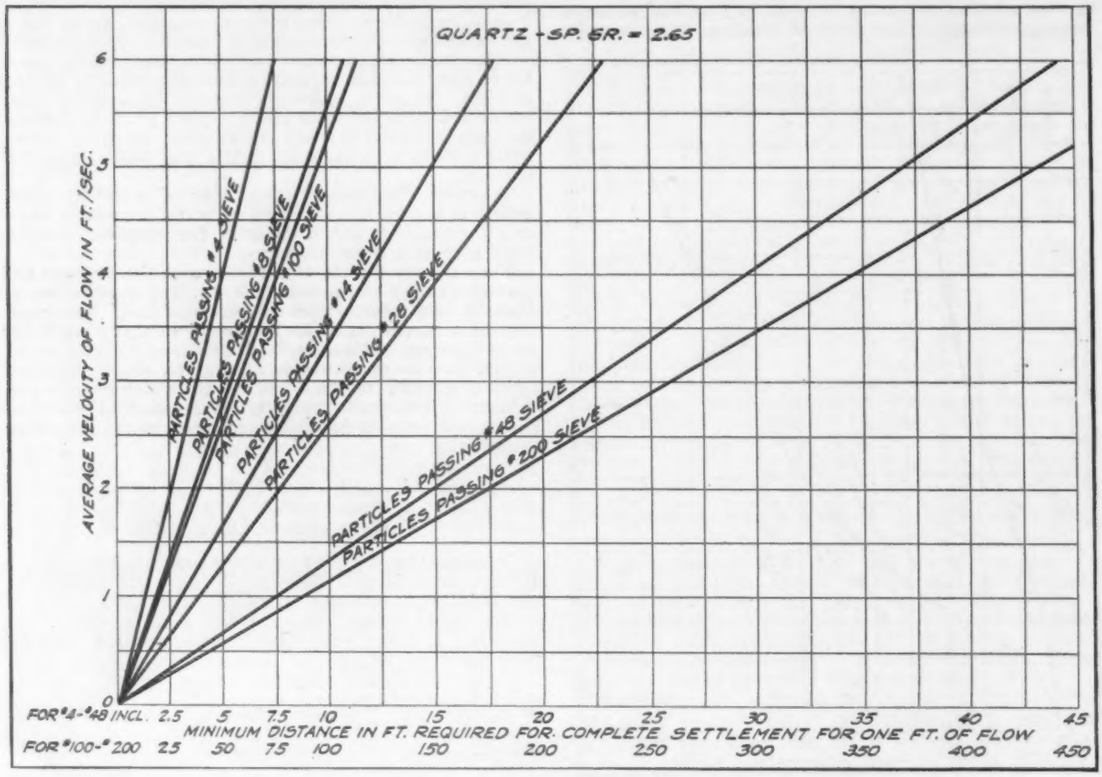

QUARTZ - SP. GR. = 2.65
PARTICLES PASSING #4 SIEVE
PARTICLES PASSING #8 SIEVE
PARTICLES PASSING #14 SIEVE
PARTICLES PASSING #28 SIEVE
PARTICLES PASSING #48 SIEVE
PARTICLES PASSING #100 SIEVE
PARTICLES PASSING #200 SIEVE
AVERAGE VELOCITY OF FLOW IN FT./SEC.
FOR #4-#48 INCL.
FOR #100-#200
MINIMUM DISTANCE IN FT. REQUIRED FOR COMPLETE SETTLEMENT FOR ONE FT. OF FLOW

Fig. 3. Ideal minimum distances required for settlement of quartz particles. Distances obtained by combining vectorially the velocity of settlement in still water with the velocity of flow in the settler, eddy currents neglected.

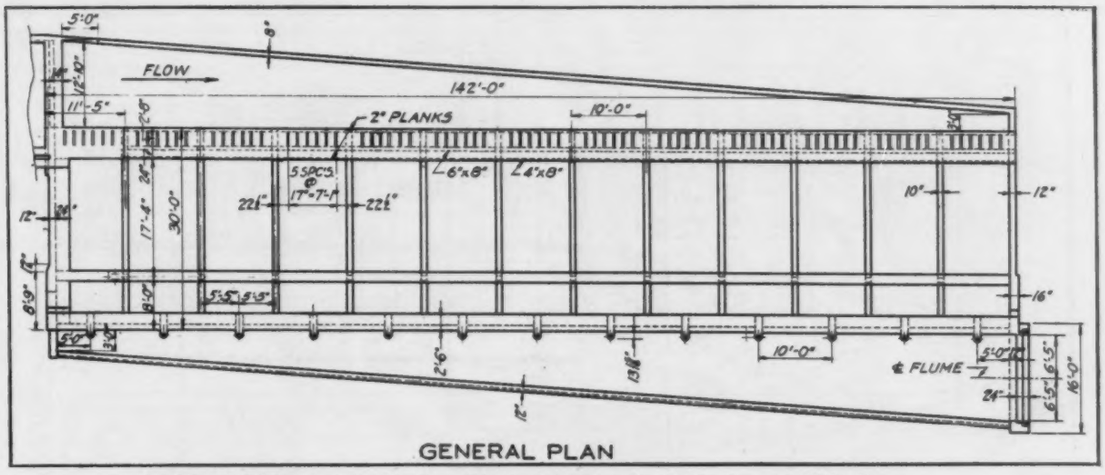


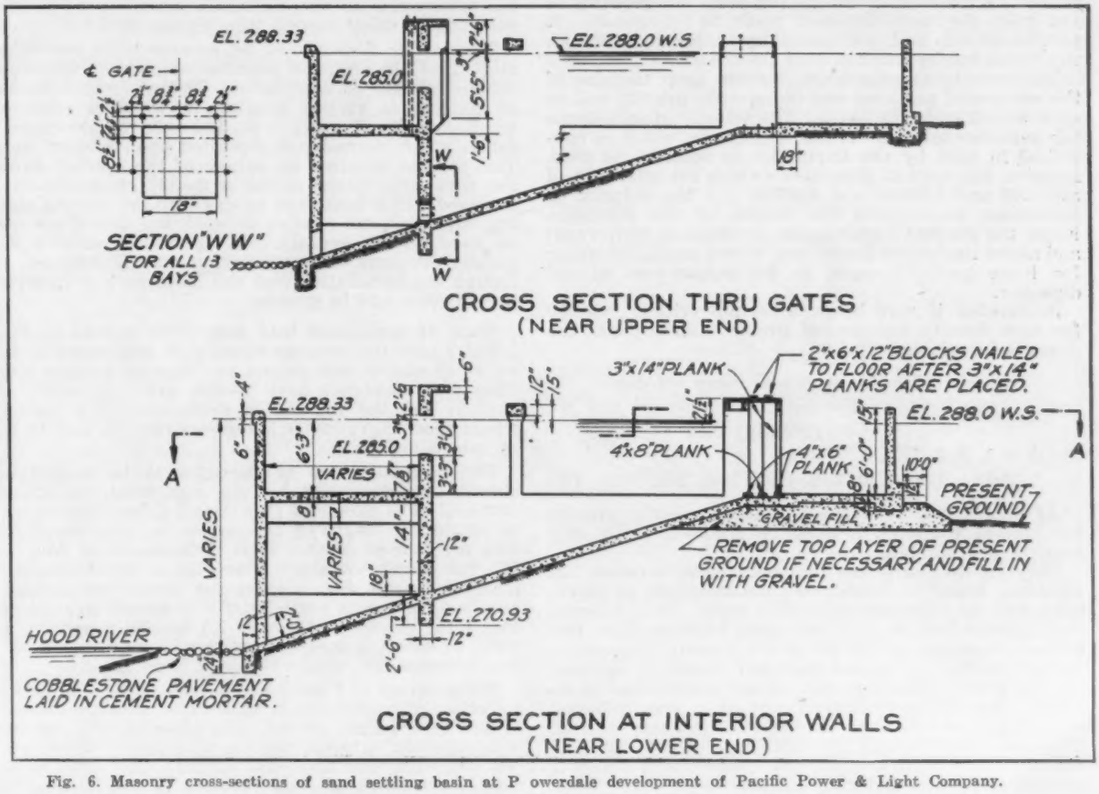
Fig. 5. Settling basin on the Powerdale development of the Pacific Power & Light Company.

strands of current continually are passing upward and downward and are as continually dividing and blending. Particles of debris too light to resist the lower elements of the current are swept upward and retained in the body of the stream through a process analogous to the stirring of the domestic pot.

While thus incorporated, they are impelled downward by gravity and all but the very finest particles actually move downward with reference to the surrounding water. From time to time they may touch the bottom of the channel, but only to be lifted again by the next adequate wash of water. The average speed of the resultant motions, referred to the surrounding water, is greater than the constant rate of descent at which the particle would move in still water. Therefore, the work of suspension measured by all the motions through the water is greater than the work of simple subsidence. While many factors are involved it is highly probable that streams are retarded by their suspended load. If this is true there is a capacity for suspension co-ordinate with a capacity for traction. For each suspended material and with any slope and velocity it is possible by increasing the load so to retard the current that it is barely competent to suspend debris of that grade and the stream is then loaded to capacity.

Normally the suspended particles in a stream are of many sizes and all tend to reduce velocity. Some of these particles are near the limit of competence and any increase in quantity will so reduce the velocity that these no longer can be held up. As to the coarsest material the stream is loaded to full capacity, but not as to finer material. The addition of finer material will cause the arrest of some of the coarser, but will increase the total load. A similar statement was made in regard to traction.

The reaction of the tractional load on velocity affects primarily and chiefly the zone of saltation, but there also is a general retardation of the stream. The reaction of a suspended load reduces all velocities includ-


EL. 288.33
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EL. 288.0 W.S.
℄ GATE
SECTION "W W" FOR ALL 13 BAYS
CROSS SECTION THRU GATES (NEAR UPPER END)
3"x14" PLANK
2"x6"x12" BLOCKS NAILED TO FLOOR AFTER 3"x14" PLANKS ARE PLACED.
4"x8" PLANK
4"x6" PLANK
VARIES
PRESENT GROUND
GRAVEL FILL
REMOVE TOP LAYER OF PRESENT GROUND IF NECESSARY AND FILL IN WITH GRAVEL.
EL. 270.93
HOOD RIVER
COBBLESTONE PAVEMENT LAID IN CEMENT MORTAR.
CROSS SECTION AT INTERIOR WALLS (NEAR LOWER END)

Fig. 6. Masonry cross-sections of sand settling basin at P owerdale development of Pacific Power & Light Company.

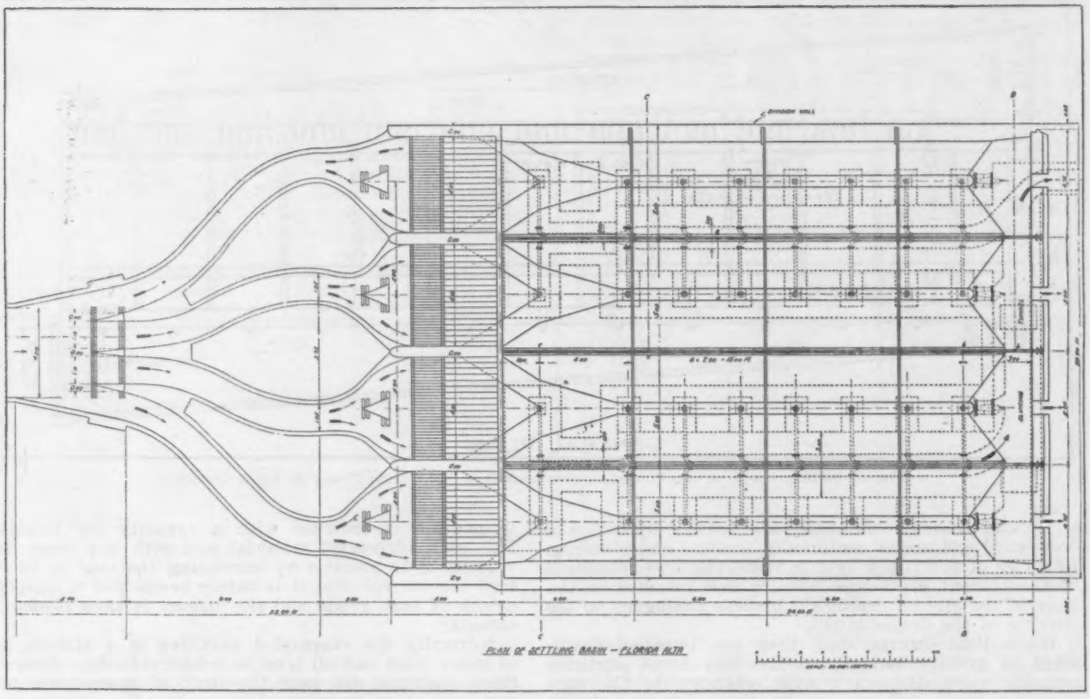


Fig. 7. Sand box at Florida Alta plant, Santiago, Chile.

ing those of the tractional load. Thus the magnitude of each load affects the capacity of the stream for the other load and it also affects the conditions of competence for suspension and competence for traction.

In natural channels the partition of the load is modified greatly by the variation of discharge and by the condition of the debris supply. The conditions of partition come to differ in pools and over shoals and usually suspension ceases altogether while traction still is continued. With flood discharge the partition probably is not quite the same for deep pools as for shoals. A portion of the load will travel by suspension through the deeps, but by traction over the shoals.

The velocity of subsidence depends upon the size of the suspended particles and the specific gravity and to some extent upon the shape. The velocity of subsidence for particles below a certain magnitude, which is controlled in part by the impurities in solution, is zero. Between two critical diameters (which for quartz sand are 0.02 and 0.00084 and 0.00192 in.) the velocity of subsidence varies with the square of the diameter. Below the smaller diameter the variation is more rapid and above the larger diameter it is less rapid, becoming for large particles equal to the square-root of the diameter.

Suspension is rare below a certain critical velocity for each density and size of grain. Kennedy has the formula for silting:

$$V_o = C\ d^{0.64}$$

V_o = critical mean velocity
d = depth
C = (usually) 0.84

Depth = 1, 2, 3, 4, 5, 6, 7, 8, 9
V_o = 0.84, 1.30, 1.70, 2.04, 2.35, 2.64, 2.92, 3.18, 3.43

As this formula considers neither specific gravity nor size of particles, it must be assumed to be only roughly approximate.

There is no sharp line of demarcation between the velocities which no longer can maintain silt in movement and the velocities which will occur. It is believed that a broad belt of velocities exists between these two critical velocities, within which silt already loosened or brought in through a head gate will remain in solution, but the bed nevertheless will remain undisturbed as to scour. Material easy to transport when once loosened may be difficult to scour. Higher velocities may be used in deeper channels with the same type of bed material. Silting and scouring are phenomena of entirely different natures and follow radically different laws.

Theoretical Settler Design

Type of tractional load only—The velocity of flow through this type of settler should be reduced to the point where the tractional load up to the desired limit of fineness no longer can be carried. The length of a settler of this type is governed by the capacity for debris storage desired. The velocity of flow through the settler should be calculated considering the available storage space for debris filled. A skimming wier at the lower end of the settler is desirable to prevent debris from being carried through the settler.

The settler floor should be arranged for convenient and rapid sluicing and possible erosion of the sluice channel should be considered. The preferable method of sluicing is ground sluicing in which a relatively small quantity of water is washed over the accumulated debris which normally is deposited upon a steep slope. This method requires an outage of the conduit during the time of sluicing unless a double compartment is provided. If it is desired to speed up the time of sluicing, high-pressure nozzles to wash the debris out may be used advantageously. In the latter case a still greater economy in water saving may be effected, although the installation cost and labor cost of emptying the settler would be greater.

Type of suspended load only—The curves in Figs. 1 and 2 give the average velocity of settlement in still water of quartz and galena particles of various sizes. These two materials have specific gravities widely divergent and the velocity of settlement of a material whose specific gravity falls between the two may be had by interpolation.

The minimum size of particles to be settled out should be determined by the considerations already outlined. The curves of Figs. 3 and 4 then may be used to obtain the length of the settler for any velocity of flow per foot of depth. Thus if the depth of flow is 6 ft., the lengths obtained from Figs. 3 and 4 should be multiplied by 6. Fig. 3 gives the theoretical distances required for quartz particles of 2.65 specific gravity and Fig. 4 for galena particles of 7.5 specific gravity. Material of different specific gravity will require interpolation between the results obtained from these.

These curves of Figs. 3 and 4 vectorially combine the velocities of settlement in still water with the velocity of flow through the settler. The effect of eddy currents was neglected in preparing the diagrams. Where very low velocities are used and smooth flow lines maintained, the effect of eddy currents in maintaining the

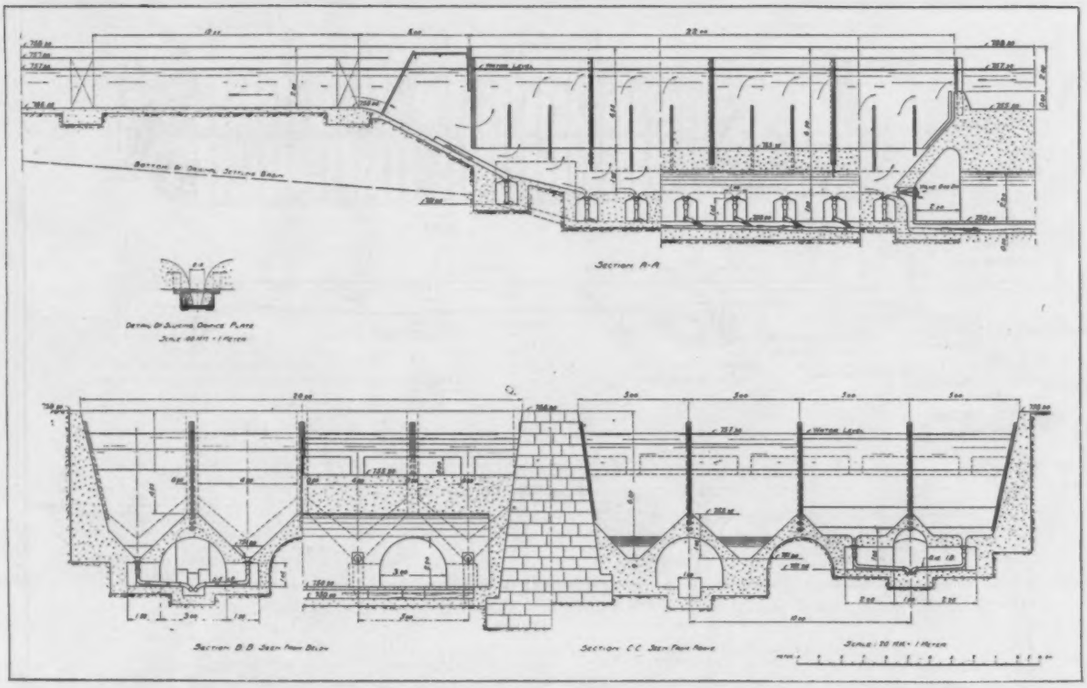


Fig. 8. Details of sand box at Florida Alta plant, Santiago, Chile.

material in suspension will be very limited. Where eddy currents probably will be present lengths of settlers greater than those obtained direct from the diagrams, or interpolation thereof, should be used.

It should be emphasized that settlers for the suspended load should be so designed as to reduce eddy currents to the absolute minimum. Baffles or irregularities of any sort in the floor or walls should be avoided. Training walls to equalize the velocity over the cross-section may be used to advantage.

Means for sluicing the settled debris conveniently should be provided, as in the case of the settler for the tractional load.

Settler for Combined Tractional and Suspended Load—A settler to combine the functions just outlined is not a simple matter for design. With a greatly depressed floor to provide ample storage for tractional debris, the length of settler properly to take care of the suspended load will be very great. In most cases it will be desirable to have separate structures for each of these duties.

Where separate structures are not used it may be economical to limit the storage space for the tractional load and design for frequent sluicing by using double compartments or similar devices.

Types of Settlers in Use

An example of a well-designed conduit intake is the Kern No. 3 intake of the Southern California Edison Company. This structure illustrates the principle of

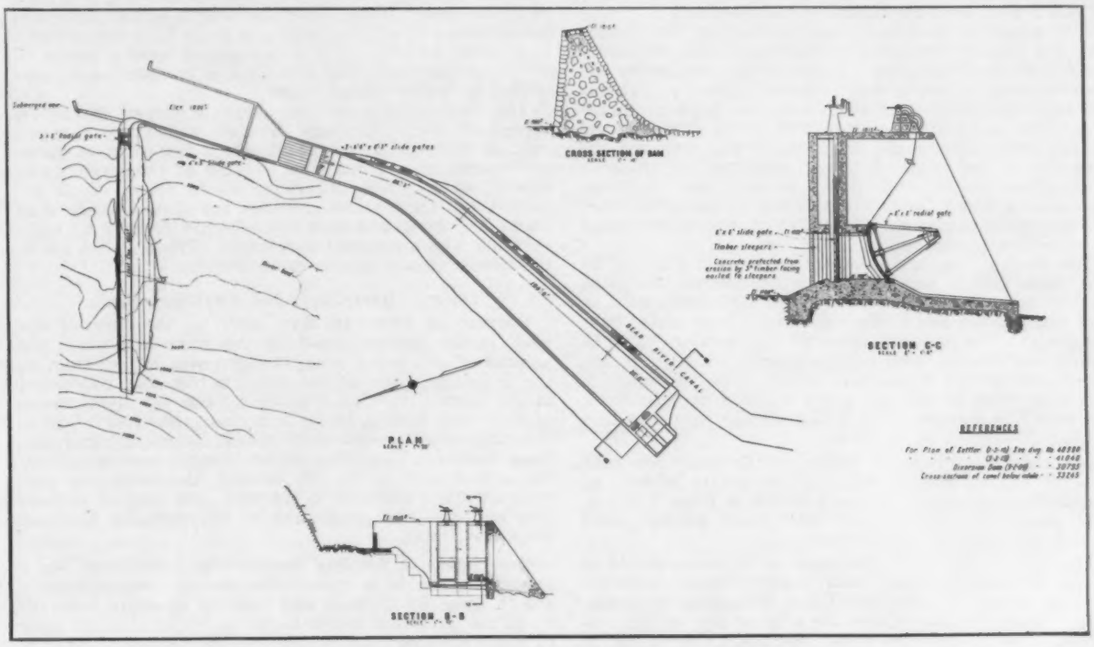


Fig. 9. Bear River settler of Pacific Gas and Electric Company.

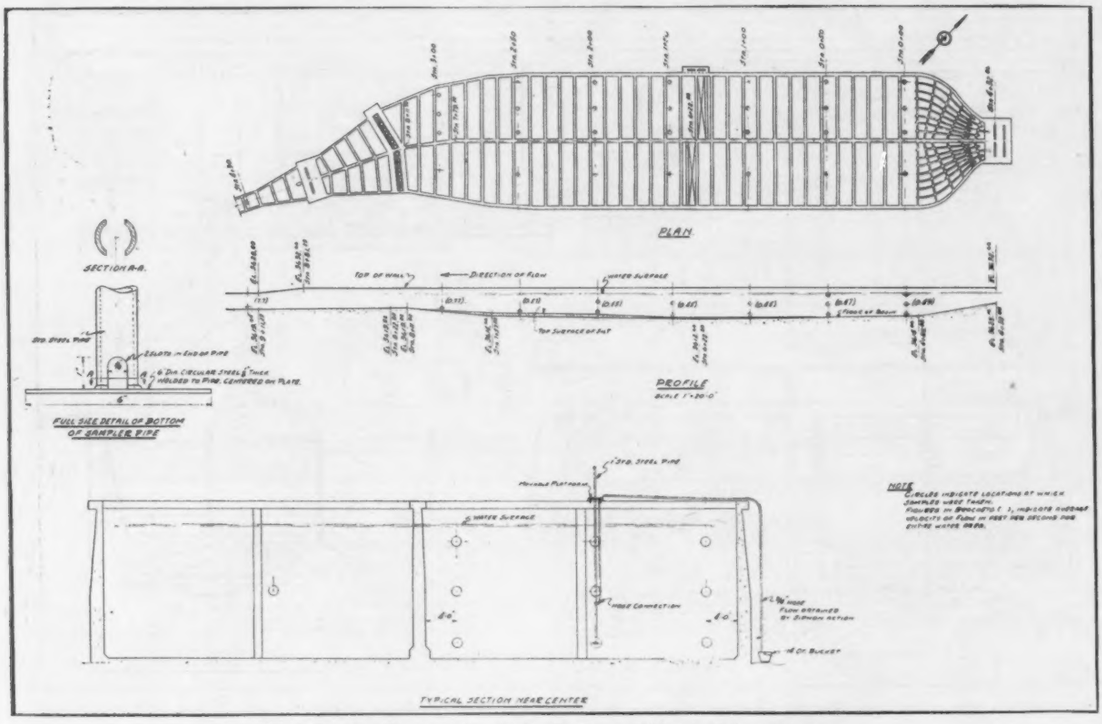


Fig. 10. Kern River settling basin, Southern California Edison Company.

locating a sluiceway in front of the intake to keep the channel clear and also of skimming the top water off by raising the sill of the intake, thus preventing the entrance of the larger debris.

In Fig. 10 is illustrated a classic example of a settler designed for handling the suspended load. Curved training walls at the entrance distribute the velocity evenly and reduce the formation of eddy currents. The double compartments permit sluicing the settled debris in the one side without interfering with the operation of the plant. Through the deeper portion the velocity is ½ ft. per sec. and is very effective in settling very fine silt. (See Hydraulic Power Committee N.E.L.A. Report, 1924, p. 41. The tests described in Section V of this report were conducted on this settler.)

The upper Bear River Canal settler of the Pacific Gas and Electric Company (shown in Fig. 9) effectively traps the tractional load. Prior to its installation expensive canal cleaning was required annually, but has not been necessary since the settler has been in operation. The Bear River carries very large quantities of mining debris during the flood season and although the capacity of the settler is large, sluicings as often as every three hours sometimes are required. A lower sand settler and a forebay at the end of the canal catch the suspended material. (See p. 43 of report mentioned in preceding paragraph.)

The Spring Gap sand settler (shown in Fig. 12 as first constructed) was also constructed after the plant was in operation. This settler did not work well as first constructed and baffle walls have been added subsequently. The velocity through the settler was not evenly distributed and eddy currents picked up the debris and carried it past the settler. The absence of a skimming wier at the lower end assisted in permitting the debris to escape. Practically all the debris in this conduit is carried by traction.

An interesting type of settler is the sand box constructed on the Florida-Alta hydro-electric project at Santiago, Chile, in 1913-14 and shown in Figs. 7 and 8. This structure was built by and under patents held by Henri Dufour of Switzerland.

The settler has four channels each composed of a series of compartments with hopper-shaped bottoms and separated by cross-partitions extending vertically from a short distance above the edge of the hoppers to within a few feet of the water surface. The object of these baffles is to give a slow upward velocity. At the bottom of each hopper is an orifice through which the settled material is discharged continuously.

It is claimed that all material above 40 mesh is removed effectively by this settler. The extremely large quantity of debris to be settled out necessitated this rather unique form of settler, 4,500 cu.yd. per day being carried by the 700-sec.-ft. conduit. The quantity of water used to effect the continuous debris sluicing is not stated.

The settler of the Powerdale plant of the Pacific Power & Light Company is shown in Figs. 5 and 6. This plant is located on the Hood River, Ore., a glacial stream carrying great quantities of debris. The water enters a tapering compartment on one side and is turned at right-angles along the entire length of the structure into a series of settling bays. In these bays the velocity is reduced greatly. The water passes over a series of wiers on the opposite side into a compartment connected with the conduit below.

The floor of the settling bays is sloped toward a series of 18-in. openings through which the trapped sand is wasted. In operation only a few of these gates are opened at any one time because of the large wastage of water which otherwise would occur. It is reported that these small openings are choked easily with sticks and bark and that deposits are formed by eddy currents where removal is difficult. Trouble with ice in the winter season also is experienced.

Tests on Kern River No. 3 Settling Basin

Purpose of Test—In May, 1927, at the time of the peak in the spring runoff of the river and when the amount of silt being brought down was higher than at the ordinary stage of the river a test was conducted at the Kern River No. 3 settling basin for the purpose of obtaining from a basin in actual operation information that might be of value in the design of other settling basins. The information sought was primarily the actual path of the silt through the basin and consequently the distance it traveled and rate of deposition and also the proportion of silt actually removed from the water.

Description of Settling Basin—The Kern River No. 3 settling basin is a concrete structure approximately 400 ft. long, 80 ft. wide and varying in depth from 18 ft. at the upstream end to 20 ft. at the middle and back to approximately 13 ft. at the downstream end. A wall in the middle divides the structure into two basins

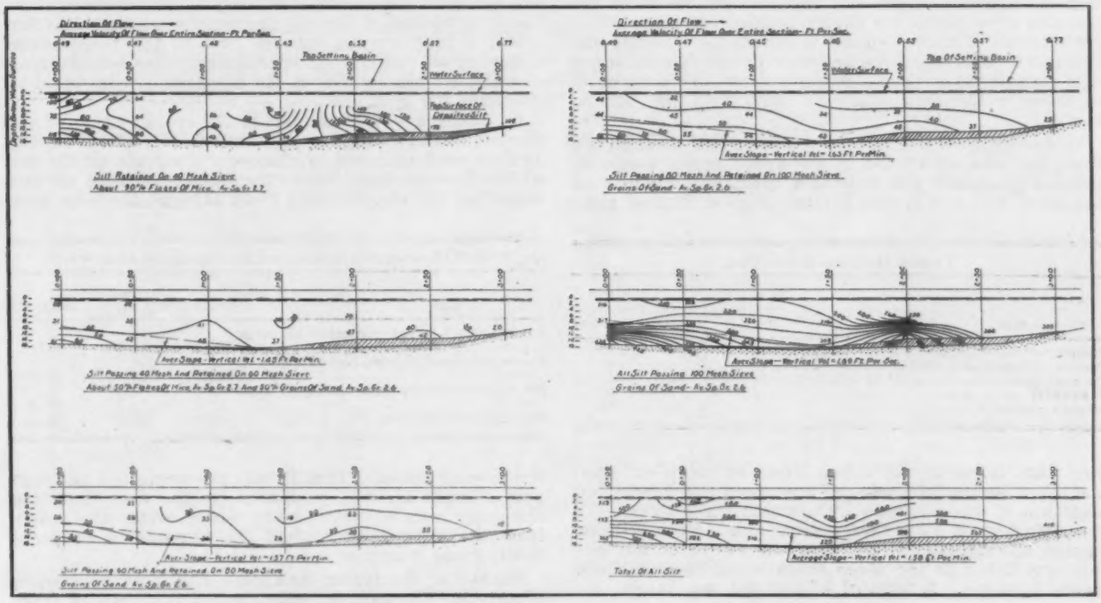


Fig. 11. Diagrams indicating the path of silt passing through the settling basin of Fig. 10.

that are just alike except for a slight variation at the lower end where the structure narrows down. Baffle walls at the upstream end split the flow into eight channels into each basin, the purpose being to obtain a uniform flow over the full width of the basin where the water enters the basin proper. The two basins are both used during regular operation of the plant, each taking approximately half of the flow. Sluice gates located at both ends of each basin provide means of shutting off either basin for the purpose of sluicing out accumulated silt while maintaining flow through the other basin. Sluice gates at the outlets of depressed channels near the center of each basin provide means of washing out the silt and discharging it into the river.

The upper end of the settling basin is about 430 ft. downstream from the intake at the river, the water flowing through a concrete flume to the basin. The intake is at the end of a low dam across the river and is at right-angles to the dam. This dam creates a comparatively small and shallow pond but this pond serves as a settling basin for probably the coarsest silt brought down by the river. At the time of a shutdown of the power plant in March, 1928, the sluice gates in the dam were opened and the water behind the dam drawn down, exposing the surface of the bottom of the pond except for a narrow channel through which the river was flowing. The pond had become silted up to a depth of several feet with a comparatively coarse sand, much coarser than any obtained in the samples from the settling basin.

The general layout of the settling basin is shown in Fig. 10.

Method of Making Test—The method adopted to ob-

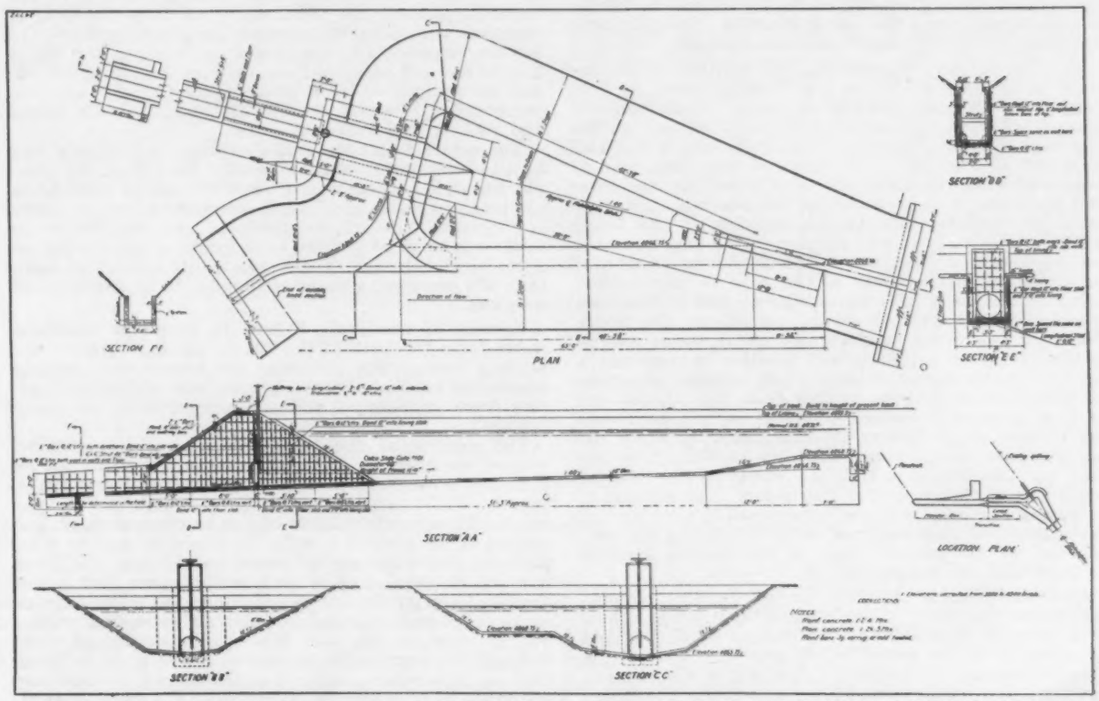


Fig. 12. Combined settler and sand trap on the Philadelphia ditch, Spring Gap development, Pacific Gas and Electric Company.

tain the samples of silt and the locations at which the samples were taken are shown in Fig. 10. Because of the element of time required to obtain the samples and further to analyze these samples in the laboratory it was considered desirable to keep down the number of samples to the minimum consistent with the desired results.

It was believed that as the water passed through the basin the amount of silt in the upper levels would be reduced gradually and become a negligible quantity at the lower end and it was for this reason that no samples were taken at the upper levels at the lower end; and, also, as the two sides of the basin are practically idenitical it was not considered worth while to make a complete test on more than the one side. However, one sample at each station and near the center of the section was taken in the other basin to serve as a check on the first one. A total of 78 samples was taken.

TABLE II—Vertical Velocities.

Size	Vertical Velocity Ft. Per Min.
Passing 40-mesh and retained on 60-mesh sieve	1.45
Passing 60-mesh and retained on 80-mesh sieve	1.57
Passing 80-mesh and retained on 100-mesh sieve	1.63
Passing 100-mesh sieve	1.69
All sizes combined	1.58

TABLE III—Percentages of Silt Deposited in the Basin.

Size	Percentage Deposited
Retained on 40-mesh sieve	74
Passing 40-mesh sieve and retained on 60-mesh sieve	95
Passing 60-mesh sieve and retained on 80-mesh sieve	89
Passing 80-mesh sieve and retained on 100-mesh sieve	96
Passing 100-mesh sieve	53
All sizes combined	66

It was desirable to obtain as large a volume as practicable for each sample but in view of the large number of containers to be handled it was decided that a large bucket would best serve the purpose. To obtain a greater volume than one bucketful the procedure was to fill the bucket, then after allowing it to stand for several hours so that the silt all settled to the bottom, to siphon off the water leaving 1 in. on the bottom to insure that none of the silt be drawn off and to fill the bucket again from the same location. In this way samples of 8 to 10 busketfuls were obtained.

For the purpose of obtaining the samples at the desired definite locations in the flowing water a 1-in. steel pipe was used, the bottom end of which had two slotted holes cut in it and a 6-in. plate welded on, the pipe centering on the plate. The detail of this pipe-end is shown in Fig. 10. The object of the plate was to insure drawing the water off from a well defined level and particularly to be sure that silt was not sucked up from the bottom when taking samples at the lower levels. A ¾-in. hose was coupled to the pipe near the bottom and this hose was sufficiently long to permit thrusting the suction end of the pipe to any desired point in the basin with the discharge end of the hose reaching to the ground on the outside of the basin. With the end of the sampler pipe under water and by means of siphon action it was possible to maintain a steady flow through the hose. The sampler pipe was marked to show lengths in feet from the suction end so that in order to obtain a sample at any point and any desired depth it was necessary only to carry the sampler pipe to that point, start the siphon action and push the pipe down so that the mark for the desired depth was at the surface of the water. The amount of water that the hose held was determined in advance and this amount of flow was run off after placing the suction end of the sampler pipe at the desired location before filling the sample bucket.

After completing the full run of samples as outlined above the water in each bucket finally was drawn off to a small quantity and the residue of silt washed by means of a fine jet of water into jars marked for identification as to location from which the sample came, the jars sealed up and later sent to the laboratory for analysis. The actual quantity of silt obtained from the 8 to 10-bucket sample necessarily was small, from about 1 to 3 grams, but the flow in the river began dropping off rapidly and consequently was not bringing down much silt so that it did not seem worth while to continue the test.

In addition to the samples in the cross-section of the flowing water, samples of the silt deposited on the bottom were obtained by dragging the plate on the end of the sampler pipe across the bottom stirring up this deposited silt and bringing it up through the hose with the flowing water. That it was the deposited silt that was brought up was evidenced by the fact that this discharge was a very muddy water while the water from the other samples had the appearance of practically clear water.

TABLE IV—Analysis of Deposited Silt Passing 100-Mesh Screen.

Size	Percentages Group I	Group II	Group III
Passing 100-mesh and retained on 150-mesh sieve	32.4	22.7	21.1
Passing 150-mesh and retained on 200-mesh sieve	27.6	18.9	18.2
Passing 200-mesh and retained on 270-mesh sieve	26.0	28.8	30.3
Passing 270-mesh sieve	14.0	29.6	30.4

Method of Analyzing Samples—The laboratory work of anlyzing the samples consisted of (1) grading them into several sizes by means of sieves and determining the weights of each of the several sizes and (2) of determining the specific gravities of each of the graded sizes. While the quantities of the samples to work with were small this work was done carefully by an experienced chemist and it is believed that the laboratory work is accurate and reliable.

A preliminary analysis of some of the bottom samples showed that the amount of silt retained on sieves coarser than 40 mesh to the inch was practically negligible and therefore it was decided not to attempt to grade for anything coarser than a 40 mesh. As a matter of fact practically all of the material retained on the 40-mesh sieve was a flaky mica. It was found also that a relatively large percentage of the silt passed the 100-mesh sieve, but in view of the large number of samples to be analyzed it was thought that the number of grades should be kept down to five sizes and that the sizes that would be of most interest would be material retained on the 40, 60, 80 and 100-mesh sieves and all material passing a 100-mesh sieve. All of the material passing the 100-mesh sieve from the several samples was lumped together in three groups—(1) bottom samples, (2) samples from stations 0 + 00 to 2 + 00 and (3) samples from stations 2 + 50 to 3 + 00, and an analysis of each group made to determine the percentages retained on 150, 200 and 270-mesh sieves and passing the 270-mesh sieve.

The detailed procedure of analyzing each sample was first to burn out all organic matter, then wash the sample through the successive sieves; next to back-wash the retained material off each sieve into a crucible; then to dry the material throughly in the crucible in an oven; and finally to weigh each grade of the sample on a chemical balance. There was in all a total of more than 400 component parts of samples to be handled and weighed.

Results of the Test—Figure 11 shows in diagrammatic form the path of the silt in passing through the settling basin. Six diagrams are shown representing separately each of the five grades into which the samples were segregated and one representing the total sample.

The results of the laboratory analysis first were worked up in terms of the number of grams of silt of each grade per cu.ft. of water. This, combined with the velocity in ft. per sec. at the point where the sample was taken gave the number of grams per sec. passing a section of an area of 1 sq.ft. It might be well to note that the velocities are all based on dividing the total flow by the total area at any section, thus giving the average velocity for the full section. No attempt was made to determine actual velocities at individual points, but in view of the fact that the velocities of flow through the settling basin are so small it is believed that no appreciable error was introduced by this assumption. Three samples were taken at each station at

TABLE V—Laboratory analysis of samples; determination of grading.

Sta.	Line	Location Depth	No. of Bucketfuls in sample	Vol. of Sample (Cu. Ft.)	Weights of several grades of the deposit in percentage of total dryout 40-mesh	60-mesh	80-mesh	100-mesh	100	Total Wt. Sample—Grams
	A	2.0	11.0	4.6969	22.2	7.6	5.0	7.7	57.5	2.166
		8.0	11.0	4.6969	15.4	6.1	4.0	7.9	66.6	2.263
		14.0	11.0	4.6969	18.1	7.7	6.1	10.8	57.3	3.323
		Bottom A			2.4	13.6	8.4	32.2	43.4	196.000
	B	2.0	10.0	4.2730	10.4	6.1	5.9	9.5	68.1	1.875
		8.0	10.5	4.4850	18.4	6.5	5.9	10.7	58.5	1.781
		14.0	11.0	4.6969	18.7	9.3	7.5	10.9	53.6	2.787
0 + 00		Bottom B			2.8	12.9	12.2	20.8	51.3	6.167
	C	2.0	10.0	4.2730	25.0	7.9	6.3	7.9	52.9	1.957
		8.0	10.0	4.2730	11.5	6.5	6.5	8.2	67.3	1.619
		14.0	10.0	4.2730	9.3	7.7	7.3	11.5	64.2	2.530
		Bottom C			8.4	10.6	11.7	18.0	51.3	1.501
	D	7.5	9.0	3.8491	12.0	5.7	6.6	8.2	67.5	1.020
		Bottom D			2.1	10.0	12.5	20.7	54.7	7.410
	A	2.0	10.0	4.2730	8.7	4.0	3.4	5.5	78.4	1.436
		8.0	10.0	4.2730	7.4	5.8	5.6	10.4	70.8	1.671
		14.0	10.0	4.2730	12.3	7.1	4.8	10.1	65.7	2.268
		Bottom A			2.4	18.5	16.9	30.7	31.5	94.640
	B	2.0	10.0	4.2730	16.8	9.5	5.6	7.0	61.1	2.232
		8.0	10.0	4.2730	12.1	6.7	4.8	8.9	67.5	1.839
		14.0	10.0	4.2730	20.2	6.9	5.1	9.2	58.6	2.548
0 + 50		Bottom B			4.1	14.4	14.0	19.0	48.5	4.472
	C	2.0	10.0	4.2730	14.8	6.0	4.9	8.5	65.8	1.498
		8.0	10.0	4.2730	17.1	7.8	5.3	8.0	61.8	2.213
		14.0	10.0	4.2730	6.1	8.6	5.8	9.2	70.3	1.796
		Bottom C			2.1	17.2	14.7	28.7	37.3	45.907
	D	7.5	9.0	3.8491	5.9	4.8	3.9	7.5	77.9	1.204
		Bottom D			1.2	6.8	9.5	18.2	64.3	4.021
	D	7.5	Extra Sample		4.0	3.0	2.0	7.0	84.0	0.100
	A	8.0	1.0	0.4579	6.6	9.6	6.6	11.2	66.0	0.303
		15.0	10.0	4.2730	10.9	4.0	6.1	9.0	70.0	1.387
		Bottom A			2.3	22.7	5.7	26.3	43.0	236.500
	B	8.0	10.0	4.2730	11.6	9.3	7.0	9.7	62.4	2.212
		15.0	10.0	4.2730	5.1	7.9	7.0	11.8	68.2	2.059
1 + 00		Bottom B			4.0	33.5	15.5	18.9	28.1	76.750
	C	8.0	10.0	4.2730	10.9	6.9	6.0	7.5	68.7	1.743
		15.0	10.0	4.2730	9.4	10.7	6.5	10.0	63.4	2.683
		Bottom C			5.3	18.9	43.0	16.1	16.7	112.700
	D	8.0	9.0	3.8491	9.2	5.2	4.1	7.1	74.4	1.163
		Bottom D			2.6	18.9	13.8	23.9	40.8	68.160
	A	8.0	10.0	4.2730	11.0	9.3	4.8	7.3	67.6	1.672
		15.0	10.0	4.2730	27.1	11.6	4.0	6.9	50.4	2.232
		Bottom A			1.3	9.6	9.0	20.6	59.5	34.790
	B	8.0	10.0	4.2730	9.8	6.3	3.7	7.6	72.6	1.582
		15.0	10.0	4.2730	7.5	4.8	5.4	8.8	73.5	2.031
1 + 50		Bottom B			1.1	7.5	10.6	18.3	62.5	8.770
	C	8.0	10.0	4.2730	5.9	4.8	4.3	8.5	76.5	1.927
		15.0	10.0	4.2730	6.1	4.5	5.5	9.3	74.6	1.905
		Bottom C			4.0	9.4	12.8	22.1	51.7	23.030
	D	8.0	2.0	0.8818	3.8	5.2	6.7	7.7	76.6	0.658
		Bottom D			2.1	9.9	9.6	22.5	55.9	35.730
	A	6.0	9.0	3.8491	31.0	7.6	6.1	5.3	50.0	1.224
		12.0	9.0	3.8491	27.2	6.0	4.2	5.0	57.6	1.325
		Bottom A			1.5	3.4	4.0	13.5	77.6	19.580
	B	6.0	9.0	3.8491	29.7	7.5	4.4	6.8	51.6	1.234
		12.0	9.0	3.8491	16.9	6.5	4.9	8.1	63.6	1.598
2 + 00		Bottom B			2.2	7.6	11.9	18.7	59.6	40.469
	C	6.0	9.0	3.8491	27.3	7.6	4.3	7.0	53.8	1.750
		12.0	9.0	3.8491	11.9	6.1	6.7	8.4	66.9	2.311
		Bottom C			1.4	8.3	8.5	19.8	62.0	12.610
	D	7.0	8.0	3.4252	51.4	7.2	3.0	3.8	34.6	2.815
		Bottom D			1.7	6.1	7.4	16.8	68.0	34.800
	A	12.0	8.0	3.4252	28.4	11.3	5.1	6.4	48.8	1.628
		Bottom A			1.0	2.7	3.2	9.3	83.8	18.690
	B	12.0	8.0	3.4252	25.8	4.8	3.6	7.4	58.4	1.327
2 + 50		Bottom B			2.3	6.9	6.8	15.8	68.2	26.650
	C	12.0	9.0	3.8491	29.0	5.5	4.6	5.9	55.0	1.526
		Bottom C			2.5	7.0	7.9	18.2	64.4	35.510
	D	12.0	8.0	3.4252	7.7	5.5	3.7	7.3	75.8	0.874
		Bottom D			1.4	3.5	5.1	17.6	72.4	39.033
	A	10.0	9.0	3.8491	16.6	6.6	3.3	5.1	68.4	0.876
		Bottom A			1.5	5.4	5.7	18.9	68.5	79.817
	B	10.0	9.0	3.8491	8.0	4.8	4.2	6.5	76.5	1.159
3 + 00		Bottom B			1.8	12.6	14.6	23.9	47.1	53.775
	C	10.0	9.0	3.8491	9.4	3.3	3.7	6.8	76.8	1.028
		Bottom C			1.3	8.6	10.8	25.6	53.7	52.202
	D	10.0	6.0	2.5774	7.1	5.2	4.5	7.8	75.4	0.736
		Bottom D			1.8	5.3	5.8	19.8	67.3	69.449
4 + 50			8.0	3.4252	11.5	1.1	1.9	1.1	84.4	0.532

corresponding depths; at 4 ft. from each of the side walls and at the middle of the section. The average of the results from these three points then was taken as representing the average for the full width of the basin and when combined with the width of the basin in feet gave the total amount of silt per sec. passing a section the full width of the basin and 1 ft. in height. This figure then was converted into terms of grams per min. as it was in more convenient form to work with and perhaps more readily comprehended as decimal fractions could be eliminated without appreciable error. These figures, then, were the ones used in making up the diagrams and, specifically, they represent for the location at which each figure is placed the total amount

of silt in grams per min. passing a section the full width of the basin and 1 ft. in height. By using these points as a basis it was possible, by interpolation, to put in lines of a nature similar to contours which represent the continuous line throughout the basin at which the amount of silt in the water is the same. By showing the several grades on separate diagrams it is possible to follow the paths of the different sizes as they pass down through basin.

It may be well to call attention to the decided upward deflection of the curves near the lower end of the basin in all of the diagrams. This would appear at first to be inconsistent, but when it is noted that the deposited silt has given a decided upward inclination to the bottom and also increased the velocity of flow it would seem reasonable to expect that the water was given an upward swirl which would carry much of the silt upward with it and this, of course, would show up in the curves. In the diagram of the "silt retained on the 40-mash sieve" a condition is shown which at first would seem to be an impossibility since it would indicate that there was a greater amount of silt of that grade near the lower end than actually came in at the upper end. However, as has been noted, the material retained on the 40-mesh sieve is made up almost entirely of flaky particles of mica and these are picked up and carried along in the swirling water much more readily than the round grains of sand. Due to the building up of the bottom of an upward inclination which might tend to cause swirling action and which certainly increases the velocity, and due to the fact that at the time the tests were made the flow was greater than at some other times of the year, it is quite possible that the water actually picked up some of the mica particles previously deposited on the bottom. It would seem probable that at times when there was very little silt on the bottom of he basin this upward deflection of the suspended silt would not occur. It also emphasizes the importance of keeping the basin well cleaned out.

From the "contour lines" on the diagrams of Fig. 11 it is possible to put in by estimation a line which represents the average slope or path of the silt in the water and from the known average velocity of flow the vertical velocity can be computed. The diagram for the 40-mesh sieve was too irregular to allow even approximating an average slope. The vertical velocities for the others are as shown in table II.

Another matter of interest obtained from the test was the determination of the percentages of silt removed from the water by the basin. By plotting a curve of quantities at station 0 + 00 near the entrance of the basin it was possible to compute the total amount of silt entering the basin which was tested. Sufficient measurements were not taken in the other basin to obtain the quantity for that basin and while the two basins are practically identical, even slight variations at the entrance channels make quite a difference in the proportion of the total amount of flow through the two basins. Measurements were taken by sounding as to the total amount of silt that had been deposited in the two basins. The last time previous to the test that each of the basins had been cleaned out was in May of the previous year, both at the same time. Therefore it was just about one year that was represented by the total accumulation of deposited silt in each of the basins. The left-hand basin had a total of 367 cu.yd. and the right-hand basin a total of 408 cu.yd of deposited silt. It was considered more logical to assume that the quantities of silt entering the two basins at the time that the test was taken were in this ratio rather than an equal amount in each one. On this assumption and basing the amount of silt remaining in the water after leaving the basin on the sample taken in the outlet flume, the following table shows the percentages of each of the different sizes of silt deposited in the basin:

It may be noted that a high percentage of the sizes retained on the 60, 80 and 100-mesh sieves are removed by the basin; that about one-fourth of that retained on the 40-mesh sieve, which consists almost entirely of flaky particles, passes on through the basin; and that nearly one-half of that passing the 100-mesh sieve passes through the basin. The component parts of the silt samples passing the 100-mesh sieve were lumped together into three groups as noted above and determinations to finer gradings made as shown in Table IV.

The specific gravity determinations shown in Table VI were made on the various silt samples after screen analysis. Three series of screened samples were collected.

1. All bottom samples.
2. All samples from station 0 + 00 to 2 + 00 except bottom.
3. All samples from station 2 + 00 to 4 + 50 except bottom.

The determinations were made in the Le Chatelier apparatus, A.S.T.M. D55-24, and with a burette for the smaller samples.

TABLE VI—Specific gravity of silt deposits.

1. Specific Gravity of Bottom Samples

Portion	Percentage	Weight Grams	Displacement C.Cs.	Specific Gravity
Retained on 40-mesh (mica)	25.675	10.50		2.45
Retained on 60-mesh	48.235	18.50		2.61
Retained on 80-mesh	50.000	19.10		2.62
Retained on 100-mesh	50.000	19.00		2.63
Passing 100-mesh	50.000	18.60		2.69
Screen tests on portion passing 100-mesh: (30 min. in "rotap" machine—dry.)				Specific Gravity
Retained on 150-mesh	32.4			2.64
Retained on 200-mesh	27.6			2.64
Retained on 270-mesh	26.0			2.72
Passing 270-mesh	14.0			2.76

2.—Specific Gravity of Sample 0 + 00 to 2 + 00.

(Samples too small for reliable tests.)

Portion	Percentage	Weight Grams	Displacement C.Cs.	Specific Gravity
Retained on 40-mesh		7.535	2.75	2.74
Retained on 60-mesh		4.316	1.70	2.54
Retained on 80-mesh		2.888	1.05	2.75
Retained on 100-mesh		5.430	2.00	2.72
Passing 100-mesh	37.700	14.30		2.64
Screen tests on portion passing 100-mesh: (30 min. in "rotap" machine—dry.)				
Retained on 150-mesh	22.7			
Retained on 200-mesh	18.9			
Retained on 270-mesh	28.8			
Passing 270-mesh	29.6			

3.—Specific Gravity of Samples 2 + 00 to 4 + 50.

(Samples too small for reliable tests.)

Portion	Percentage	Weight Grams	Displacement C.Cs.	Specific Gravity
Retained on 40-mesh		5.201	1.90	2.73
Retained on 60-mesh		1.345	0.50	2.69
Retained on 80-mesh		0.880	0.35	2.52
Retained on 100-mesh		1.101	0.42	2.62
Passing 100-mesh	12.032	4.50		2.67
Screen tests on portion passing 100-mesh. (30 min. in "rotap" machine—dry.)				
Retained on 150-mesh	21.1			
Retained on 200-mesh	18.2			
Retained on 270-mesh	30.3			
Passing 270-mesh	30.4			

Pressure Tunnels*

The work covered in this report was initiated under the leadership of J. M. Gaylord, Southern California Edison Company, chairman of the hydraulic power committee in 1926-27.

A condensed summary of information concerning all pressure tunnels reported by member companies of the Pacific Coast Electrical Association is given in Table I. Special reference is made in the following discussion to such phases of the subject of pressure tunnels as cannot be clearly expressed in this summary.

General

Pressure tunnels may be either lined or unlined depending upon many features, principally upon the character of the formation through which the tunnel is driven. If the formation will permit an undue amount of leakage, as frequently will occur in lava formations and occasionally in badly fissured granite ground, the use of concrete lining generally is necessary or advisable.

(See Table I, page 408.)

An unlined pressure tunnel also requires that the ground be amply firm and of a character to hold its position without excessive yielding under the pressure involved. The maximum head under which a tunnel is to operate frequently determines whether or not the section should be lined. Lining sometimes is adivsable

* Report of subcommittee of hydraulic power committee—I. C. Steele, chairman. R. C. Booth, R. L. Bryant, Walter Dreyer, J. W. Jourdan, H. A. Krueger, C. M. Mardel, F. J. Mills, E. G. Waters.

from the standpoint of improving the hydraulic functions.

The amount and character of the overburden also become of major importance in the choice of the section. Estimated or actual cost of construction has a decided influence in the adoption of either a lined or unlined tunnel, assuming the formation such as to permit the use of either. The size of the bore for the unlined section may permit the use of power equipment not usable if the smaller lined section were adopted. If both sections under consideration are smaller than required for the proper use of heavy power equipment and larger than the minimum size for economic driving it may in some cases be economical to adopt a lined section due to the great difference in the coefficients of friction.

Size Required to Permit Use of Power Shovel—The minimum size of tunnel to accommodate a power shovel depends mainly upon the shape of the tunnel and the type of shovel to be used. Special provisions frequently are made in the reconstruction of the shovel arm. Very close clearances are permitted when necessary.

The following tunnels (some of which are flow tunnels) were driven wholly or in part with power equipment.

Unlined Tunnel

Maximum Allowable Head—The maximum allowable head for an unlined tunnel depends upon the type of ground and the overburden. Rock with open seams may be satisfactory for very low heads, but may permit the escape of too much water under higher heads. The greatest static head for the unlined tunnels reported is about 150 ft., as developed in the Big Creek No. 5 tunnel of the Southern California Edison Company. This tunnel is nearly 14,000 ft. long, practically entirely unlined and driven through gray granite from Shaver Lake to Tunnel No. 2. The long Balch tunnel of the San Joaquin Light & Power Corporation operates under a maximum static head of 143.6 ft., the formation grading from coarse to fine-grained hard granite. No undue leakage has occurred in either instance.

Minimum Overburden—Other Than at Portals and Adits—Minimum permissible overburden is dependent upon many things, the geological formation being perhaps the most important. The amount of solid rock and the stratification and its position should have considerable bearing on the design. If the rock strata are in horizontal or nearly horizontal planes or in planes more or less parallel to the slope of the hillside there may be danger of a tunnel failure through successive failures of these strata due to the development of hydrostatic pressure (from leakage) against the upper layers where the weight of the overlying material is insufficient to withstand it. An illustration of this is the failure of the Sand Canyon siphon on the Los Angeles aqueduct, described later under the heading, "Failures." For absolute safety against this "hydraulic jack" action the overburden should equal the static head. This is applicable also to a lined tunnel if not fully reinforced. Minimum overburden for the unlined Kerckhoff tunnel of the San Joaquin Light & Power Corporation was established at the static head plus 5 ft. For the unlined Balch tunnel of the same company, which follows down a steep sided canyon, it was required that the minimum section of overburden be capable of withstanding the full static head as a true gravity section dam, based upon the assumption that the pressure be applied on a vertical plane passed through the plane of the tunnel alignment.

Shapes—The rectangular-shaped section predominates in unlined tunnels although circular and horseshoe-shaped sections occasionally are adopted. One of the prime factors in determining the shape is the consideration of the equipment to be used and the method of driving. The formation also may have a decided influence, particularly as regards the adoption of a flat arch versus one with a smaller radius. Hydraulic properties also should be considered.

The Balch tunnel has a nominal 12 x 12-ft. rectangular section with the roof slightly arched. The shape of this tunnel section was governed by a perconceived method of driving in order to give adequate clearance for driving equipment.

Overbreak—The extent of overbreak varies considerably with different ground formations as well as within the same general character of ground. The method of drilling and shooting and the care with which the driving operations are conducted materially affect the amount of overbreak. The following table is indicative of the measured overbreak for several tunnels.

TABLE III—Tunnels Driven with Mucking Machines.

Kern Canyon (S.J.L.& P.)	13 x 13 ft. Rect.	Armstrong Mucking Machine
Melones	13.5 ft. Circle before lining.	Electric Conway Mucking Machine.
Spaulding Enlargement.	10 x 13.5 ft. Horseshoe.	Conway Mucking Machine

In connection with the measurement of overbreak, mention should be made of a device called a "proebstograph" developed by D. W. Proebstal, superintendent of tests, Portland Electric Power Company. This apparatus (believed to be patented) consists essentially of a large pantograph mounted on a transit tripod and constructed so that it can be turned through 360 deg. of arc and an exact picture of the tunnel cross-section drawn upon a paper chart, the center of which would be the pivotal point of the pantograph arm. It was used first in connection with the construction of a tunnel at the Bull Run hydro-electric plant of that company. Apparently it gave excellent results. It is stated that accurate tunnel excavation cross-sections were taken at the rate of from 12 to 15 sections per hour. A partial description of the apparatus and its operation as submitted by the designer follows. (See also Fig. 1.)

TABLE IV—Measured Overbreak.

Tunnel	Shape (Diam. Inside Lining)	General Formation	Per Cent Overbreak
Copco No. 1	16 x 16 ft. Horseshoe	Andesite, volcanic conglomerate, some volcanic mud.	21.0
Copco No. 2	16 x 16 ft. Horseshoe	Broken and solid andesite	29.0
Spaulding (Lined Sect.)	8 ft. 8 in. Circle	Solid granite	30.0
Halsey No. 5 & No. 6. P. G. & E.	8 ft. Circle	Hard diorite	25 and 30
Melones	12 ft. 12 in. Horseshoe 12 ft. Circle	Solid greenstone	23.0
Big Creek No. 5 (Shaver Lake toTun. No.2)	8 ft x 11 ft. Rectang. (Unlined)	Gray granite	29.5
Balch S. J. L. & P.	12 x 12 ft. Rect. with flat arch (unlined)	Coarse to fine-grained hard granite	20.0 aver.
Tunnel No. 3. S. C. E. Co.	21 x 21 ft. Rect. with flat arch (unlined)	Granite	24.3
Florence Lake S. C. E. Co.	15 x 15 ft. Rect. with flat arch	Granite	31.3
Tunnel No. 7 S. C. E. Co.	13 ft. 2 in. x 14 ft. Horseshoe (unlined)	Granite	12.0

The dimensions of the picture would bear a definite ratio to those of the cross-section such as 1/24 which was the ratio selected for the device built for use in the tunnel referred to above.

The pantograph is constructed of four light wooden arms held together at the hinged points by means of brass plates and closely fitted steel bolts. A pencil holder with an adjustable point is located in the first vertical arm near the pivot which is at one end of the lower horizontal arm. The upper horizontal arm is held in fixed relation to the lower by means of two vertical arms. At the end of the upper arm is a small rubber-tired wheel which rolls easily over the rough surface of the tunnel. The distance between the pivot point and the pencil is 1/24 of the distance between the pivot and the outer edge of the wheel on the upper arm. The drawing or chart board is about 1 ft. square and has projecting through

TABLE II—Tunnels Driven with Power Shovel.

Name	Company	Shape	Size	Type and Size of Shovel	Length of Shovel Arm	Size of Bucket
Pit No. 3	P. G. & E	Circular	Driven horseshoe 20 x 20 ft. inside timbers	Erie "A"	10.5 ft. sticks	⅝ yd.
Big Creek No. 8	S. C. E.	Rect. with 10 ft. arch	20 x 20 ft.	Marion No. 40		
Kerckhoff	S. J. L. & P.	Rect. with flat arch	18 x 18 ft.	Marion No. 20 and No. 40	13 ft. Boom, 7.5 ft. dipper sticks	1¼ yd.
Florence Lake	S. C. E.	Rect. with flat arch	15 x 15 ft.	Special Marion No. 25		

TABLE I—Data on Pressure Tunnels.

		Pacific Gas and Electric Co.						Big Creek No. 1	Big Creek No. 2	Southern Califor
	Item	Spaulding	Halsey No. 5 and No. 6	Wise No. 10	Pit River No. 1	Pit River No. 3	Melones	Huntington Lake To Pen. No. 1	P. H. No. 1 To P. H. No. 2 Penstock	Big Creek No. 5 Shaver Lake To Tun. No. 2
General:										
Length—Total	a-1	4,450	2,576	436	10,070	21,230	Outlet valve to pens.	3,045	21,760	13,866
Lined	2	940	2,576	436	10,070	21,230	4,400		Outlet 1000	
Unlined	3	Flow 3,510					All except portals	20,760		13,866
Capacity sec.-ft	4	500	350	400	1.800	3,000	1,500	480	560	
Grade	5	0.00188	0.0134 and 0.0079	0.01757	0.003	0.0031	0.00157 and 0.004	0.002	0.0032	0.005 and 0.001
Static head:										
Min.	6		10	61	On floor 20	On ℄ 24				0
Max.	7	200	40	65	On floor 51	On ℄ 86	219	140	100	150
Formation	8	Solid granite	Hard diorite	Earth and broken rock	Solid Lava to broken lava and earth	Agglomerate	Solid greenstone	Gray granite	Gray granite	Gray granite
Alignment	9				1 angle	2 angles	8 angles			
Max. angle	10	16°-01′	Straight	Straight	35°-49′	11°-40′	58°-27′			
Min. curvature	11				Rad. 50′		Rad. 55′			
Deviation from center line	12				4 in.					
Date in service	13	1913	1916	1916	1922	1925	1927	1913	1913	1921
Unlined Tunnels:										
Max. head	b-1	Flow 0						140	100	150
Min. overburden										
Horizontal	2									
Vertical	3									
Cross-section										
Shape	4	Rect. 10′ x 13′ Av.						Circular 12′ Dia.	Circular 12′	Rect. 8′ x 11′
Area	5	115.7						113.1	113.1	88
Maximum velocity	6	4.35						4.2	5.0	
Overbreak	7	Lined Sect. 30%	25% and 35%				23%			29.5
Leakage										
Assumed	8									
By test	9									
Flow coefficient "n"										
Design	10	0.035						0.035	0.035	0.035
From test	11									
Power equipment	12	St. face	St. face	St. face	Bench and heading	Wall-plate drafts	St. face method	Bench and heading	Bench and heading	Full face
(Shovel, mucker, etc.)		Hand mucking	Hand mucking	Hand mucking	Hand and Machine mucking; stor. batt. locomotives	Bench and heading Air shovel, mucker stor. batt. locomotives	Elec. Conway mucking machine, stor. batt. locomotives	Hand mucking Mule cars	Hand mucking Mule cars	Shovel-loader, stor. batt. locomotive
Lined Tunnels (Including lined portions of unlined tunnels)										
Max. head	c-1	200	40	65	Floor 51	Stat. 86	Design h = 285	140	100	
Cross-section					8570′	1500′	Unreinf.	Reinf.		
Shape	2	Circular	Circular	Circular	Horse-shoe	Circ.	Circular	Horse-shoe	Circ.	
Diameter	3	8′ 8″	8′ 0″	8′ 0″	13′ 0″ x14′3″	14′0″	19′ 0″	12′x12′	12′	
Area	4	59.0	50.3	50.3	154	154	283.5	120.9	113.2	
Max. velocity	5	8.5	7.0	7.96	11.7	11.7	10.6	12.4	13.2	
Flow coefficient "n"										
Design	6		0.014				0.014	0.014	0.014	
From test	7				0.0128		0.0127	0.0136		
Factors influencing adoption (Formation and watertightness)	8	Static head and tightness	Pressure and formation	Static head and formation		Static head and formation	Driving room and formation			
Timbering	9						None			
Type of packing	10	None			Wood					
Unreinforced lining	11	Length 720′	None	None		320′	3,985′			
Min. overburden										
Horiz.	12	100					80			
Vert.	13	100					80			
Pressure grouting (yes or no)	14	Yes			Yes—certain sects.	Yes	Yes	Yes	Yes	
Pressure	15	110 lb.			100 lb.	100 lb.	90 lb.			
Quan. per ft.	16				Aver. 0.5 sack cement		145 sk. cem. 1.75 sk. sand			
Min. thickness	17	6 in.			9 in.	12 in.	9 in.	9 in.	12 in.	
Concrete or gunite	18									
Reinforced lining	19	Length 220′				20,890	415	None	None	
Min. thickness	20	10 in.	8 in.	8 in.	9 in.	12 in.—8 in. in front of timber	9 in.			
Min. distance to steel	21	2 in.	5 in.	5 in.	2½ in.	8½ in.	6 in.			
Load assumptions	22	Ground carry. half pressure.	Ground carry. half pressure.	Ground carry. half pressure.						

TABLE I—Data on Pressure Tunnels.

nia Edison Co.		San Joaquin Light and Power Corp.			Southern Sierras Power Co.	California-Oregon Power Company	Great Western Power Company			
Big Creek No. 8 P. H. No. 2 To P. H. No. 8 Penstock	Kern River No. 1 Penstock	Kerckhoff	Kern Canyon	Balch		Copco No. 2 No. 1 and No. 2	Tunnel No. 2 Caribou	Tunnel No. 3 Caribou	Big Bend	Item
5,633	1,172	16,943	8,363	19,345	1,950	2,440 ... 1,105	9,295	554	15,044	a-1
	1,172			125		2,440 ... 1,105	Whole length ...	Whole length ...	Whole length ...	2
All except adit and outlet		16,943		19,220	1,950	0				3
1,800		2,100	800	720		3,000	Pres. 900, Fut. 1,200	900	Pres. 2,600, Fut. 3,500	4
0.004	40° incline	0.003	0.003	0.0033	0.025	0.00742 ..0.00452	0.008	28°-11'-39"	0.00033—0.0058	5
80	900	65	48	80 to 143.6	70	50'	56	13?	Pres. 44, Fut. 134	6
Hard gray granite	Granite	Granite	Blocky granite to glacial draft	Coarse to fine-grained hard granite	Hard granite	Lava, variable	132	395	Pres. 113, Fut. 205	7
							Broken lava, shale and serpentine	Shale and serpentine	Hard schists and slate	8
				4 angles		1 angle	3 angles	Straight	1 angle	9
	40°			55°-58'		53°	46°-24'		31°-29'-30"	10
	Rad. 46.25'			50' Rad.		200' Rad.	Rad. 40'			11
				No Deviation		None				12
1921	1906	1920	1921	1927	1910		May, 1921	May, 1921	Nov., 1908	13
80		65	72	143.6						b-1
				For h = 86.6: 370 / For h = 139.3: 370						2
2,400 ft.	3,200ft.	Max. stat. head + 5'		120	155					3
Ellip. 14'x17'	20 x 20 with 10' Rad. arch	Rect. with flat Arch		Rect. with flat Arch						4
		18' x 18'	13' x 13'	12' x 12'	Rect. 5' x 6'					
200	357	320	170	144						5
9.0	5.05	6.75	4.7	5.0						6
				Aver. 20		21% ... 29%				7
										8
										9
0.035		0.040	0.035	0.035	0.035					10
		For V = 4.26 N = 0.0312								11
Bench and heading, hand muck., stor. batt. locomotives	Pioneer heading steam shovel	For V = 2.41 N = 0.0311								12
		Head. and bench steam shovels. stor. batt. locomotives	Enlargement muck. machines, stor. batt. locomotives	Muck. machine..	Hand muck..	Hand mucking..				
Near adit and portals 80	900			125', at intake 80		50	132	395	Pres. 113 Fut. 205	c-1
	Circular		A-1 B C-1 C-2	Horseshoe		Horseshoe	Circular	Circular	Horseshoe	2
	7.5			12'-0" x 12'-6", 6' rad. arc		16' x 16'	10'-0"	9'-8"	14—16 ft.	3
	44.2			130		216.4	78.54	73.44	220.5	
				5.5		13.9	Pres. 11.5 Fut. 15.3	12.3	Pres. 11.8 Fut. 15.9	4
			92 74 104 114							
			8.7 10.8 7.7 7.0			0.014	0.014	0.014	0.014	5
0.014			0.015							6
										7
				Formation		Hyd. requirem'ts	Static head and formation	Static head and formation	Friction	8
							Whole length	Whole length	510 ft.	9
							12x12-3" lagging Wood	12x12-3" lagging Wood	Dry packing	10
									Whole length except 121 ft. steel pipe at lower end.	11
						100'			130	12
									60	13
No	No		No No No No			Yes			At lower portal	14
										15
										16
18 in.	9 in.					9 in.			12 in.	17
				700 ft. gunited					Concrete	18
							Whole length	Whole length		19
			12 in.	8 in.		9 in.	4" over timbers	8" inner shell, $\frac{5}{8}$" pipe 20" ave. outer shell reinf.		20
				4 in.		3 in.	6 in.			21
			Reinforce for full pressure for bad ground; half pressure for good rock that might leak	Take full static head and external pressure			Rein. for ext. pressure, rock to carry int. pressure			22

TABLE I—Data on Pressure Tunnels—Continued.

	Item	Pacific Gas and Electric Co.					Southern Califor			
		Spaulding	Halsey No. 5 and No. 6	Wise No. 10	Pit River No. 1	Pit River No. 3	Melones	Big Creek No. 1 Huntington Lake To Pen. No. 1	Big Creek No. 2 P. H. No. 1 To P. H. No. 2 Penstock	Big Creek No. 5 To Shaver Lake To Tun. No. 2
Allowable stress										
Concrete	23									
Steel	24	Stat. head 28,000 lbs.	Total head 30,000 lbs.	Total head 30,000 lbs.	16,000 lbs.	Stat. head 20,000 lbs.	24,000 lbs. for design head			
Pressure grouting	25		No	No	Some sects.		Yes			
Pressure	26	110 lbs.					90 lbs.			
Quan. per ft.	27						2.0 sk. cem. 2.8 sk. sand			
Reinforcing:										
Max. size	28	¾ in. sq.	¾ in. sq.	¾ in. sq.	⅝ in. sq., ⅞ in. sq.	1¼ in. sq.	1¾ in. sq.			
Min. spacing	29	6 in.	14 in.	10 in.	10 in., 10½ in.	5 in.	5 in.			
Length of laps	30		3′ 0″	3′ 0″	40 dia.	40 dia.	50 dia.			
Position of laps	31					Laps staggered 5′ in alt. rows	Laps at spring line			
Concrete:										
Method of placing	d-1	By hand	Air	By hand	Air	Concrete gun	Concrete gun	By hand	By hand	
Method of tamping	2					Steel forms tapped	Steel forms tapped			
Mixture	3	Gravel 1-6	1-3-6	1-3-6	1-3-5	1-2.62-3.85	1-4.2-4.1 1-2.5-2.9	1-2½-5	1-2½-5	
Slump	4					6″-8″	0″-7″			
28-day strength	5					1,700 lbs. to 2,200 lbs.	1,200 lbs. and 2,000 lbs.			
Artificial lubricant	6					Diatomaceous earth	No			
Amount	7					2% cemt. by wt.				
Construction joints:										
Transverse type	8					Grooved	Grooved			
Spacing	9					70′	40′ to 60′			
Longitudinal type (Location)	10		Invert poured first. Joint on each side		On each side of bottom invert-grooved	4 grooved in lower third—4 pours	4 grooved in lower third—4 pours			
Leakage	11					In vert. const. joints				
Method of sealing	12					Plastering				
Tunnel Leakage	e-1		Developed near portals	Developed at lower portals	50 sec. ft. max.	90 sec. ft. max.				
(Results of tests)					Reduced to 9.2 sec. ft.	Reduced to 33 sec. ft				
Method of eliminating or reducing	2			Repair and gunite surface	(Some silting up)	(Some silting up)				
Steel liners	3									
Cement wash	4		Plastering		Cement grout wash and plastering	Plastering				
Caulking	5									
Grouting	6									
Failures or Trouble:										
(Refer to Notes A, B, etc.)	f-1			Blow out, 1922						

it at its center a steel spindle which supports the pantograph. It is a cross marked with a vertical and a horizontal center line and has a (+ 0 —) scale attached to one of the sides so that the point coincides with the horizontal center line. The instrument is supported by means of a transit tripod and attached to it through a ball-and-socket joint which facilitates alignment.

The method of using the "proebstograph" is quite simple. The center line of the tunnel first is located and points set at the required intervals for the proposed sections; a level is set up at a convenient place and the height of the instrument determined; then the proebstograph is centered by means of a plumb-bob over one of the points. The long leg of the tripod must point to the rear of the chart board and in the direction of the forward stationing of the line. The instrument should be leveled and sighted for position 90 deg. to the tunnel line by means of points previously set with transit and tape on the sides of the tunnel. The height of the instrument then should be determined by means of a level and the vertical scale on the side of the chart board. Thus the instrument would be located with respect both to the vertical and the horizontal center-lines of the tunnel section.

The next step is to place a center-punched chart on the drawing board and spot upon it the position of the vertical and horizontal lines on the board. The instrument then is ready for the pantograph arm to be placed on the spindle, the nut screwed on, the pencil set and the section taken by rolling the wheel around the entire perimeter of the tunnel. The form of notes to be taken would be: station of section; height of center-line of instrument, and radial point grade.

The area of a tunnel cross-section in sq.ft. is equal to four times the area of the chart in sq.in., which may be measured by means of a planimeter. The cubic yardage excavated is equal to the product of the average of the cross-sectional areas in sq.ft. and the length of the tunnel in ft. divided by 27.

Leakage—No leakage tests of unlined tunnel in the territory of the P.C.E.A. have been reported. Volume II of the First World Power Conference contains the following data with reference to the Amsteg tunnel in Switzerland and the Lake Spuller works of the Austrian Railways:

A 500-ft. section in the granite portion of the Amsteg tunnel was tested for leakage. The surface area was 16,200 sq.ft. and the pressure 136 ft. Test indicated a leakage of 0.141 sec.-ft., or 0.0087 sec.ft. per 1,000 sq.ft. of surface. Tests in fine broken dolamite in the Lake Spuller tunnel indicated a percolation rate of 0.0985 to 0.165 sec.-ft. per 1,000 sq.ft. of area under a pressure of 1 ft.

Flow Coefficients—The value of "n" in Kutter's formula usually is taken as 0.035. Tests given in Engineering News-Record for open rock canals indicate the following values for "n":

No. 23, Vol. 91, page 936—Rough channel as blasted n = .0385 to .042.
No. 17, Vol. 98, page 685—After trimming n = .030.

Various methods of improving the flow coefficient can be adopted. Careful shooting and trimming perhaps are the most common expedients although the shooting is more apt to be given consideration in connection with the extent of the overbreak than with regard to the flow coefficient.

The 1926 World Power Conference report notes the tendency (apparently in European practice) of finishing the bottom or invert of the tunnel with concrete in order to reduce the friction losses. This concrete is cheap to install and might prove economical particularly in certain sizes of tunnels.

Tests on the Kerckhoff tunnel of the San Joaquin Light & Power Corporation gave values of "n" as follows:

For velocity of 4.26 ft. per sec. "n" = 0.0312.
For velocity of 2.41 ft. per sec. "n" = 0.0311.

Lined Tunnels

Maximum Head—The maximum head under which a lined tunnel may be used safely may not depend upon whether or not it is to be reinforced so much as upon whether or not the formation will withstand the pressure involved without undue yielding. The following from Vol. II of the First World Power Conference is worthy of note:

TABLE I—Data on Pressure Tunnels—Continued.

nia Edison Co.		San Joaquin Light and Power Corp.			Southern Sierras Power Co.	California-Oregon Power Company	Great Western Power Company			
Big Creek No. 8 P. H. No. 2 To P. H. No. 8 Penstock	Kern River No. 1 Penstock	Kerckhoff	Kern Canyon	Balch		Copco No. 2 No. 1 and No. 2	Tunnel No. 2 Caribou	Tunnel No. 3 Caribou	Big Bend	Item
.....	.....	.....	.....	650 to 800	.....	600	.....	.....	.....	..23..
.....	.....	.....	.....	16,000 and 23,000	.....	16,000	.....	.....	.....	..24..
.....	.....	.....	No.	No.	.....	Yes	.....	.....	.....	..25..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..26..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..27..
.....	⅞ in. steel lining	.....	.....	¾ in. sq.	.....	1¼ in. sq.	1 in. sq.	⅞ in. plates	.....	..28..
.....	.....	.....	.....	4 in.	.....	6 in.	12 in.	1 in. sq.-3 in. ¢-¢	.....	..29..
.....	.....	.....	.....	40 dia.	.....	50 diam.	5'-6"	.....	.....	..30..
.....	.....	.....	.....	.....	.....	Top ¼ point for outside row. long. center line for inside bars.	Laps at hor. dia.	.....	.....	..31..
Gun	.....	.....	Concrete gun.	Air gun and carriages	.....	Concrete gun	By hand in invert gun in crown.	By hand	By hand	.d-1..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..2..
1-2½-5	1-3-3	.....	1-3-5	1-6¼	.....	1 : 2 : 4	1 : 2 : 4	1 : 2 : 4	.....	..3..
.....	.....	.....	.....	5 in.	.....	.....	.....	.....	.....	..4..
.....	.....	.....	.....	2,000 lbs.	.....	.....	.....	.....	.....	..5..
.....	.....	.....	.....	.....	.....	.....	None	None	None	..6..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..7..
.....	.....	.....	.....	None	.....	.....	.....	.....	Plain	..8..
.....	.....	.....	.....	.....	.....	40 to 60	.....	.....	60 ft.	..9..
.....	.....	.....	.....	1 on each side just above haunch	.....	Each side invert slab	In ea. side above invert	.....	Sides poured first then crown, floor last	..10..
.....	.....	.....	.....	.....	.....	.....	.....	None	None	..11..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..12..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.e-1..
.....	.....	.....	.....	.....	.....	.....	By pressure grouting and hydraulic sealing of surrounding ground. See separate rept.	.....	.....	..2..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3..
.....	Steel lining.....	.....	.....	.....	.....	.....	.....	.....	.....	..4..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..5..
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..6..
.....	Failed Jan.,1909	.....	.....	.....	.....	.....	1924. Int. pres. caused lining cracks	.....	.....	.f-1..

For pressure tunnels, procedure recommended is as follows:

If rock is strong and tight and working pressures are such as usual for such cases, tunnel need not be lined. Barberine works (Swiss) is example.

If rock in itself is tight, but contains fissures, lining should be used. For pressures up to 34 ft. a lining of rammed concrete is sufficient. Nowadays, cross-section always circular, but formerly was horseshoe or elliptical, with no allowance for side pressures.

For higher pressures or more unfavorable rock, a sheet-iron lining is necessary.

The unreinforced lining of the Spaulding tunnel is under a static head of 200 ft.

The Ritom tunnel is described herein under the heading, "Failures." Apparently the rock formation which was a soft mica schist and micaceous gneiss, yielded sufficiently under pressures from 54 to 65 lb. per sq.in. in hydrostatic pressure to open up many cracks, principally horizontal, through which considerable leakage developed. So long as the pressure at the lower end of the tunnel was kept under 14 lb. per sq.in. no appreciable leakage occurred.

The Rondout tunnel of the Catskill aqueduct (also described under "Failures") developed undue leakage under a head of approximately 100 ft. Inspection showed cracks in the 20-in. lining where mud seams had been encountered in driving. In sandstone formation cracks were from 1/16 to ⅛ in. at the spring line of the arch, and 3/16 in. in limestone with diagonal shear cracks. Sections were well grouted. It is thought that there had occurred a general movement in the limestone rock and that the sandstone merely had been compressed a little.

The Shoshone power tunnel of the Shoshone project will operate under a maximum head of 230 ft. when the project is fully developed. The tunnel is an 8.5 x 8.5-ft. horseshoe section with a lining of 9-in. minimum thickness reinforced only at the corners. Four-inch tile drains were placed at each of the four corners of the excavated section to carry away leakage and the lining was pressure grouted. A 1:2 ½:5 concrete mix was used. By using greased ropes, tar paper and mortar the grouting up of the drains was prevented.

Shapes—Where reinforcement is not required in the lining the shape probably would be horseshoe to conform to the excavation. If conditions are such as to require reinforcement for internal pressure then the lined section should be circular.

Where only a small portion of the length of a tunnel has a reinforced lining the shape of the lined section may be made to conform to the shape of the unlined section. This was done on the Balch tunnel. (See Fig. 2.)

On the Pit No. 1 tunnel of the Pacific Gas and Electric Company for low pressure in sections that required timbering which could not be removed, the horseshoe section was reinforced. The Pit No. 3 tunnel was driven horseshoe-shape to accommodate construction equipment, but was lined as a circular section, the lining being designed to carry the full static head.

Packing—Wood packing behind the timber lagging probably is satisfactory where the concrete lining is reinforced. Where wood packing is used cut-offs should be installed at intervals across the tunnel to prevent the longitudinal flow of leakage through the packing. Cut-offs would prevent the possibility of leakage being accumulated along the line of the tunnel and carried out to the portals. The indications are that this flow condition has occurred in the Pit No. 3 tunnel. In the Caribou tunnel No. 2 of the Great Western Power Company water collecting outside the lining formed a flow outside the lining toward rock contacts where the water escaped. Concrete cut-offs or barriers would prevent this longitudinal flow.

If the lining is unreinforced the packing should be

of rock or brick and pressure-grouted in order to prevent cracking of the lining (Oak Grove).

Unreinforced Lining—For absolute safety against hydraulic-jack action the overburden should equal or be greater than the static head. This hydraulic-jack action caused the rupture of the Sand Siphon of the Los Angeles aqueduct. (See "Failures.")

Fig. 1. The Proebstograph.

Lining should be pressure-grouted to prevent cracking following shrinkage of the shell from the rock when setting. The unreinforced lining of the Spaulding tunnel of the Pacific Gas and Electric Company was grouted at a pressure of 110 lb. per sq.in. The Melones tunnel of the Pacific Gas and Electric Company was very thoroughly grouted and quite accurate data regarding the pressure and amount of grout used were obtained. A brief description of these operations follows:

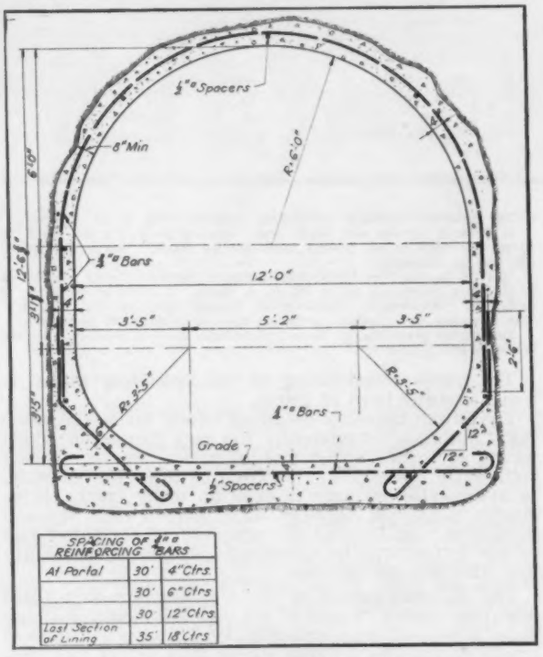
During the process of concrete lining the Melones tunnel 2-in. pipes were placed in the arch at all high points in the over-break and into all crevices. (See Fig. 3.) This procedure provided pipes at intervals of approximately 10 ft. throughout the length of the tunnel. From 30 to 60 days after the 9-in. concrete lining had been placed, cement grouting consisting of a mixture of sand, cement and water was forced through these pipes to refusal under pressures carrying from 25 to 90 lb. per sq.in. After grouting had proceeded through a wet section some seepage and small leaks appeared in the sides of the tunnel and these were partially sealed by drilling holes at the point of leakage and re-grouting with neat cement. A 1-batch home-made grout machine was used for this latter purpose.

The main grouting was done with a miniature of a standard 3-cu.yd. concrete gun mounted together with the grout mixer on a 6-wheel jumbo. This was constructed to hold about ¾ cu-yd. and to withstand an internal pressure of 300 lb. per sq.in. The grout was mixed in the mixer, which consisted of a 100-gal. oil drum having a shaft through its center to which six fan-shaped paddles were fastened. The shaft was continued through the end of the drum and an air drill was fastened to it. By keeping this well oiled it ran almost continuously day and night for three weeks without requiring repair or other maintenance. The mixer was arranged to dump directly into the grout gun. The platform surrounding the mixer could be used to store 25 or 30 sacks of material. The jumbo ran on the 3-ft.-gage tunnel track and was moved readily as desired. After the track had been removed a tugger hoist was mounted underneath the platform for moving the jumbo by means of a ⅜-in. cable and snatch-blocks.

The 1-batch grout gun consisted of a vertically mounted section of 12-in. wrought-iron pipe having both ends closed by means of plates welded on. A 4-in. plug at the top permitted the gun to be filled and a 2-in. outlet at the bottom was threaded to take the grout hose. Mixing for this gun was done by hand in a tub having a 2-in. outlet at the bottom and mounted directly over the gun, so that the outlet was just above the 4-in. plug. For conveying the grout to the holes 2-in. rubber air hose was used, while 3-in. air hose was used to connect the gun to the 4-in. air main running through the tunnel. A 1-in. hose was used for the water connections.

At each new hole the grouting was started with neat cement unless the pipe was known to be very free. A 1:2 cement-sand mixture was used for all freely flowing pipes until the grout began to move slowly, at which time a 1:1 mix was used until partial refusal, after which neat cement grout was forced in to refusal. In the lower tunnel from the top of the inclined section to 25 ft. beyond the beginning of the reinforced penstock tunnels nothing leaner than a 1:1 mix was used and this was changed to neat cement as soon as the material began to show signs of flowing slowly. For grouting the additional seepage holes neat cement only was used.

Throughout the lower and inclined tunnels and at all reinforced sections a pressure of 80 or 90 lb. per sq.in. was used. The 35 ft. of standard horseshoe tunnel across the construction adit and the closing plug also were grouted at 90 lb. per sq.in. The rest of the standard unreinforced horseshoe-section tunnel was grouted using pressures of from 25 to 30 lb. per sq.in. Some of the seepage holes were grouted at from 40 to 45 lb. per sq.in. Pressure regulating valves were used on both machines to assure constant maximum pressures.



SPACING OF ½"ø REINFORCING BARS		
At Portal	30'	4" Ctrs.
	30'	6" Ctrs.
	30'	12" Ctrs.
Last Section of Lining	35'	18 Ctrs.

Fig. 2. A lined section of the Balch tunnel.

The detailed grouting procedure was about as follows:

Ten or twelve 2-in. stop-cocks were screwed into consecutive grout pipes. The grout hose was coupled to the first valve and air turned on. This served to drive out any water behind the lining and also gave the inspector a basis for estimating whether or not the hole would take much grout. A batch of neat cement grout next was put in the gun and forced into the hole. If this was taken easily additional batches of 1:2 mix were forced in until the hole began to fill. Then a 1:1 batch was used followed by as many neat cement batches as were necessary to fill the hole to refusal. The valve then was closed and, after emptying the gun, the hose moved to the next open valve. At times grout would travel from 30 to 50 ft. and start flowing out of the other valves. These then were shut and left closed. Any grout remaining in the gun when changing mixes, or when a hole refused to take any more, was discharged

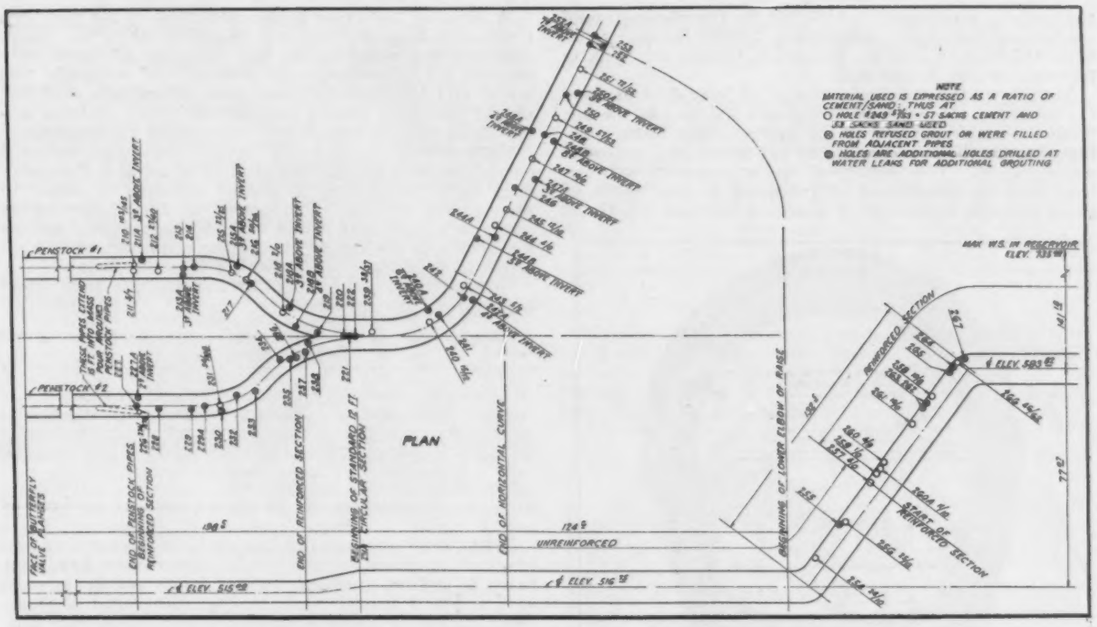

NOTE
MATERIAL USED IS EXPRESSED AS A RATIO OF CEMENT/SAND, THUS AT
HOLE #249 4.7/3.1 = 47 SACKS CEMENT AND 33 SACKS SAND USED
HOLES REFUSED GROUT OR WERE FILLED FROM ADJACENT PIPES
HOLES ARE ADDITIONAL HOLES DRILLED AT WATER LEAKS FOR ADDITIONAL GROUTING
PENSTOCK #1
PENSTOCK #2
PLAN
UNREINFORCED
REINFORCED SECTION
MAX. W.S. IN RESERVOIR ELEV. 1331.41
ELEV. 585.42
ELEV. 545.58
ELEV. 516.58

Fig. 3. Field record of grouting, Melones tunnel

back into the mixer. Only small batches were used (not over 8 sacks) as it was found that not only could the mixer mix as fas as the gun would discharge, but small batches plugged the gun less readily.

Occasionally a rocky spot in the concrete was encountered which allowed the grout to escape freely. These places were caulked with wood and left for a half hour or so to allow the cement to set before grouting was completed.

In all, 4,614 ft. of tunnel was pressure-grouted and the average use of materials exclusive of the subsequent seepage grouting was 1.56 sacks of cement and 1.91 sacks of sand per ft. of tunnel. Seepage grouting averaged 0.06 sack of cement per ft. of tunnel. Eighty-three labor shifts were required for the main grouting and 12 for the seepage grouting. An average of 193 sacks of material was placed per shift of main grouting.

The entire cost of material and labor including depreciation of equipment, but not overhead, was $4.46 per ft. of tunnel grouted. Of this amount $1.88 represented the cost of cement f.o.b. the job and $2.25 the total labor cast including hauling and handling materials, construction of special equipment, drilling and grouting.

A tabulation covering the physical details of the work is shown in Table V.

The minimum thickness is a factor which is largely dependent upon the formation and the shape and size of the tunnel. The minimum thickness shown on the general data sheet is 6 in.

In Western practice gunite has been used to prevent possible leakage in unlined tunnels as in the Balch tunnel of the San Joaquin Light & Power Corporation. Gunite also has been used for complete lining of short sections of tunnels; 400 ft. of the Melones tunnel between the intake and the irrigation outlet was lined with gunite 12 in. thick.

Reinforced Lining

As shown in the general data tabulation the minimum thickness of reinforced lining ranges from 8 to 12 in. The minimum distance to steel is shown from 2 to 8½ in. A distance of 4 in. probably would conform to conservative practice.

TABLE VI—Minimum Thickness—Unreinforced Lining.

Name	Company	Size	Min. Lining Thickness
Spaulding	P. G. & E. Co.	8 ft. 8 in. circular	6 in.
Pit No. 1	P. G. & E. Co.	13 ft. o in. x 14 ft. 3 in. horseshoe	9 in.
Melones	P. G. & E. Co.	12 x 12 ft. horseshoe	9 in.
Big Bend	G. W. P. Co.	14 x 16 ft. horseshoe	12 in.
Big Creek No. 2. (1,000 ft.)	S. C. E. Co.	12 ft. o in. circular	12 in.

The allowable stresses in the steel and concrete in relation to the static or design pressure have been influenced by the character of the formation, the total head, and other factors. Steel stresses from 30,000 lb. per sq.in. (based on the design head) to 16,000 lb. per sq.in. (based on the static head) are listed. Where designed for the static head only with no allowance being made for the weight of the material over the tunnel a steel stress of 20,000 lb. per sq.in. seems a fair value. A stress of 800 lb. per sq.in. for 2,000-lb.-per-sq.in. concrete (28 days) and a steel stress of from 16,000 lb. to 18,000 lb. per sq.in. seems good practice where the design considers the external forces.

In the report of the committee on concrete oil tanks in the Proceedings of the American Concrete Institute for 1920 the following stresses are specified to prevent leakage. For circumferential steel: 12,000 lb. per sq.in.

TABLE V—Data on grouting Melones Tunnel.

Stations	Distance Ft.	Sacks Cement	Sacks Sand	Add'l. Cement Wet Spots	Pressure Used Lbs. Per Sq. In.	Sacks Per Ft. of Tunnel Concrete	Sand	Tota
4 + 02 to 27 + 56	2,354	2,907	3,021	228	25–30	1.33	1.29	2.62
27 + 76	Closing plug	8	1	None	80–90	....	....	.....
27 + 56 to 36 + 50	894	1,400	1,612	None	25–30 (1st 40 ft. 80 lb. used)	1.57	1.80	3.37
36 + 50 to 38 + 12	162	548	978	None	80–90	3.39	6.04	9.42
38 + 12 to 43 + 95	583	644	876	None	25–30	1.11	1.50	2.61
43 + 95 to 45 + 41	140	853	1,382	10	80–90	6.16	9.87	16.03
Incline Section	120	142	100	15	80–90	1.31	0.83	2.14
46 + 30 to 47 + 91	161	215	166	11	80–90	1.40	1.03	.2.44
Manifold and Penstock Tunnels	200	497	677	1	80–90	2.48	3.38	5.86
Totals	4,614	7,214	8,813	265		1.62	1.91	3.53

for underground work and 10,000 lb. for above-ground work; and for other reinforcing 16,000 lb. per sq.in. Wall thickness based on maximum tensile strength in concrete of 150 lb. per sq.in.

The maximum spacing and size of bars depend upon the pressure, thickness of lining and distance of the bar from the inside surface of the lining. Maximum spacing of twice the covering of the bar would be considered conservative. The minimum space required between bars may be determined by requiring a clear space of twice the side dimension of a square bar and 1½ times

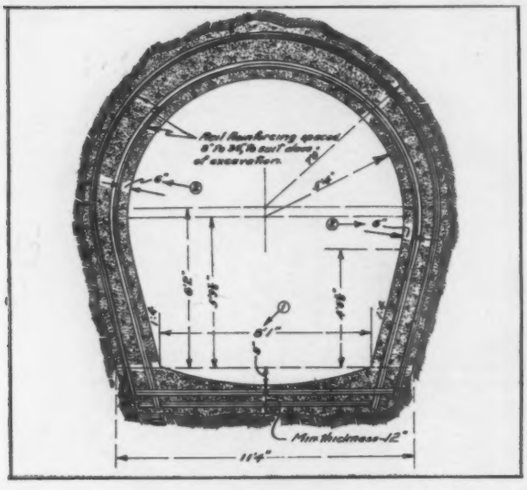


Fig. 4. Reinforced lining, Huntington-Shaver tunnel.

TABLE VII.

Name	Company	Size Bars	Spacing	Lap
Pit No. 3	P. G. & E. Co.	1¼ in. sq.	5 in.	40 dia.
Melones	P. G. & E. Co.	1⅜ in. sq.	5 in.	50 dia.
Balch	S.J.L.& P.Co.	⅝ in. sq.	4 in.	40 dia.
Huntington-Shaver	S. C. E. Co.	35 lb. rail	8 in. and 24 in.	(for external pressure.)

the diameter of a round bar. Therefore the minimum spacing is determined at the laps as there are twice as many bars at this point.

A lap of 40 diameters may be recommended for bars with clear distance between them as noted above, and a lap of 50 diameters if the bars are wired together. It is not possible usually to stagger the laps of the reinforcing bars, but it is desirable if it can be done. Best position of laps usually seems to be midway between crown and spring line with other positions midway between spring line and invert.

Various arrangements of reinforcing and laps are shown in Figs. 2, 4 and 5.

Following are examples of heavy reinforcement:

The modern method of placing the concrete above the invert by air seems to give the best results both as to economy and quality of placed material. It is necessary to exercise care to prevent the formation of pockets, by tamping the mix and hammering the forms. Openings or manholes should be provided in the forms to facilitate these operations and also for inspection.

Semi-reinforced sections may be recommended only where the pressures are low. The Pit. No. 1 tunnel may be considered as a section of the above type. (See Fig. 6.)

For low or moderate pressures European practice has recommended the use of iron liners, or a reinforced gunite layer inside the concrete lining. Grout then is forced in between the liner and the concrete. The heavy concrete lining carries the external loads.

Concrete

Diatomaceous earth and hydrated lime have been added to concrete to increase the workability, produce better flow, and lessen the separation of the ingredients. On the Pit No. 3 tunnel 2 per cent cement content, by weight, of diatomaceous earth was added and the results were very satisfactory in maintaining workability and easy flow.

A series of tests now being conducted by the Southern California Edison Company indicates that the above qualities are obtained by the addition of these substances. Little change in strength of concrete was noted and the tests to date seem to indicate that the use of not more than 4 per cent of either of these admixtures will not reduce the strength of 1:7 concrete.

Extensive tests made by one of the major railroad companies indicate the desirability of using a diatomaceous earth admixture in tunnel concrete in order to secure best results. The power of the diatomaceous earth to absorb and retain moisture apparently assists materially in the curing and in the acquirement of high strength concrete and in making it impervious.

Strength and consistency for the concrete for following tunnels are shown:

TABLE VIII.

Name	Company	Concrete Placed by	Mix	Slump	28-Day Strength
Pit No. 3	P. G. & E. Co.	Air	1/2.62/3.85	6 to 8 in.	1,700 to 2,200 lb.
Melones	P. G. & E. Co.	Air	1/4.2/4.1 or 1/2.5/2.9	6 to 7 in.	1,200 to 2,000 lb.
Balch	S. J. L. & P. Co.	Air	1/6.0/0.5	5 in.	2,000 lb.

It has been average practice to have keyways on the longitudinal construction joints. Less care has been taken in general with the vertical joints and in the case of Pit No. 3 tunnel some leakage developed through these. Thus it would seem that where large-bore tunnels which require timbering are subject to fairly high

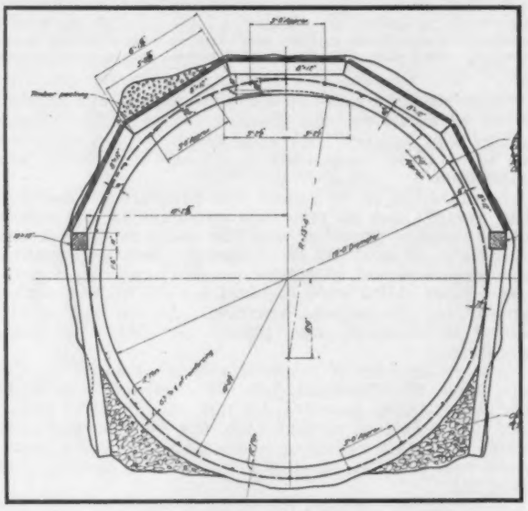


Fig. 5. Reinforced section of Pit. No. 3 tunnel.

pressures the provision of metal stops in the transverse joints should be considered. The transverse joints in the Pit. No. 3 tunnel, spaced at 70 ft., showed a uniform shrinkage opening of 1/32 in. The joints that developed leakage, as determined by backflow when the tunnel was emptied, were sealed by plastering. This plastering together with natural silting reduced the amount of leakage to a great extent.

Grade

In general the grade should be maintained as flat as design will allow in order minimize the head. The usual long pressure tunnel has a surge tank at the lower end and the maximum downward surge determines the elevation of the tunnel at the lower end. Where reinforced lining is required it may be economical to make the tank larger and thus reduce the magnitude of the downward surge and in turn reduce the amount of reinforcement required. This has been done for the proposed Pit. No. 4 tunnel of the Pacific Gas and Electric Company.

Under the usual conditions of driving from both upper and lower headings, it is in general a construction advantage to have the grade as flat as possible to avoid hauling against grade and to avoid heavy dumping in case water is encountered.

Leakage Tests in Pacific Coast Practice

The concrete-lined Pit No. 1 tunnel of the Pacific Gas and Electric Company showed a leakage of 50 sec.-ft. soon after it had been put in operation. After the measurement the tunnel was emptied and after some plastering was done, porous pockets removed and repaired, the entire lining was brushed with a cement grout. After the tunnel had been in operation for a month after the repair work was done a second test showed a leakage of 16.6 sec.-ft. A third test made nine months after the second showed a further reduction in leakage to 9.2 sec.-ft. The water flowing in this tunnel always is clear but carries a strong growth of moss and algae which may have helped reduce the leakage after the repair work had been done.

The first measurement for leakage made on the Pit No. 3 tunnel showed a leakage of 90 sec.-ft. Much of this leakage as noted by the backflow when the water was turned out was near the lower end of the tunnel line and near the portals. The vertical construction joints showed strong backflow. Repair work in the nature of plastering was done at the points showing leakage and measurement three months later, Oct. 25, 1925, showed a reduced leakage of 75 to 80 sec.-ft. The tunnel was emptied and inspected in December, 1925, and, as before, the strong backflow came from transverse construction joints particularly at points where it had been necessary to timber the section solid. Measurements taken on Feb. 4, 1926, and on March 3, 1926, showed leakage of 52 and 33 sec.-ft. respectively. Silting up of cracks is indicated.

In the case of excess leakage of the Ritom tunnel in Switzerland the leakage was reduced by plastering and by a reduction in pressure. The leakage in the Rondout Siphon of the Catskill aqueduct was reduced by lining the section with channels bent to a radius of 2 in. less than the original radius of the tunnel, riveted together and caulked, and the 2-in. space pressure grouted. To reduce leakage, the World Power Conference publication of 1926 recommends for low pressure the use of thin iron liners with pressure grouting.

Flow Coefficients

From the general data tabulation it may be noted that the average value of the coefficient "n" of Kutter's formula as used for the design of concrete lined tunnels is 0.014. An actual test on the 4,459 ft. of 12-ft. circular section of the Melones tunnel gave an average value of "n" of 0.0136 and an average value of "C" (Williams and Hazens formula) of 111. The lining was constructed with steel forms and the surface was free from rough spots and projections. The alignment had six horizontal and two vertical bends throughout its length.

Flow tests made on the Pit No. 1 tunnel (wood forms) soon after it was in operation gave a value of $n = 0.0128$. A test on the Pit. No. 3 tunnel (steel forms) gave a value of $n = 0.127$. From test measurements published in U. S. Department of Agriculture Bulletin No. 852, representative values are:

TABLE IX.

Name	Diam.	Velocity	Value of "n"	Remarks
Whitney Siphon (Los Angeles Aqueduct)	10.0 ft.	3.01	0.0132	Cement Mortar Coat
Rondout Siphon	14.5 ft.	2.84 4.58 1.58	0.0131 0.0136 0.0124	Oiled Steel Forms
Walkill Tunnel (Catskill Aqueduct)	14.5 ft.	1.58 2.84 4.64	0.0129 0.0128 0.0123	Oiled Steel Forms

Alignment

Abrupt changes in alignment of power tunnels are to be avoided wherever possible. As noted from "Hydroelectric Handbook," by Creager and Justin, recent tests tend to show that the minimum loss of head at a bend occurs when the ratio of radius to diameter of tunnel equals 5. From tables and curves in this book the following values of "K" and head loss in bends are shown for that ratio of radius to diameter.

Formula:

$$\text{Eddy loss} = h_f = Kh_v = K\frac{V^2}{2_g}$$

Records indicate that it is general practice to allow no deviation from the center line, if practically possible, in driving the tunnel.

TABLE X.

Angle	Ratio to 90	"K"	"hf" for V = 10
90	1.00	0.300	0.47
75	0.92	0.275	0.43
60	0.83	0.250	0.39
45	0.70	0.210	0.33
30	0.53	0.160	0.25
15	0.30	0.090	0.14

Appurtenances

Manholes or manways of practical size should be provided at some convenient location such as at portals, adits or behind head gates. These are important for inspection as well as for minor repair work such as stopping small leaks, additional grouting, etc.

Adit plugs should be grouted under pressure to insure water tightness. Surge chamber or secondary tunnel connections usually are a matter of special design requiring special care as to reinforcement and pressure grouting.

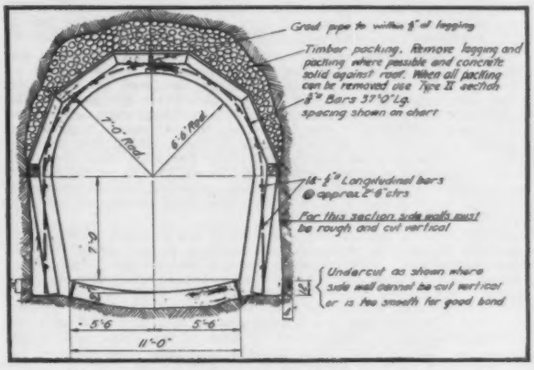

Grout pipe to within 9" of topping
Timber packing. Remove lagging and packing where possible and concrete solid against roof. When all packing can be removed use Type II section
1/2" Bars 3'1"0" Lg. spacing shown on chart
7'0" Rad.
6'6" Rad.
18-1" Longitudinal bars @ approx 2'6" ctrs
For this section side walls must be rough and cut vertical
Undercut as shown where side wall cannot be cut vertical or is too smooth for good bond
5'6
5'6
11'0"

Fig. 6. Reinforced section of Pit. No. 1 tunnel.

When crossing ravines or creeks where the tunnel emerges either for heading or from necessity the water generally is carried in a circular pipe with a supporting structure whose design is influenced somewhat by the type of foundation and the distance of the structure above bedrock.

The Rock Creek crossing of the Pit No. 3 tunnel is a reinforced concrete pipe of the same diameter as the tunnel, 19 ft., and is supported on a reinforced concrete girder structure. It is designed for continuous support along each bridge girder. The shell of the pipe has a thickness of 14 in. with an inner and outer row of reinforcing, this being made necessary by bending stresses with the pipe either partially or just full, but under no head. Stresses of 800 lb. per sq.in. in the concrete and 18,000 lb. per sq.in. in the steel were used.

Wood stave pipe with steel sleeve connections to the concrete lining inside the tunnel portals often is used. Halsey tunnels No. 5 and No. 6 of the Pacific Gas and Electric Company are connected by wood stave pipe supported on concrete cradles.

Air vents behind the head gates at the upper portal of a pressure tunnel are necessary and should be amply designed. In selecting the size of such vents consideration should be given to its use as an entrance for small construction equipment to effect possible repairs. Care should be exercised in locating the grating over the air vent to prevent injury to men when draining the tunnel with the head gates closed. Where it has been necessary to drive on adverse grade a method of draining the tunnel should be provided in case of need of inspection and repair.

Failures and Partial Failures

Failure of Kern River No. 1 Penstock—In January, 1909, the penstock tunnel of the Kern River No. 1 plant of the Southern California Edison Company failed. The following comments represent a condensed description of the penstock tunnel and failure as this description was submitted by that company.

The force main consists of an incline tunnel through solid granite driven at an angle of approximately 57 deg. with the horizontal. The tunnel begins in the bottom of the forebay and emerges at the lower end of the slope on a level with the power house floor. The operating head was approximately 900 ft. and the inside diameter 7½ ft. for the upper 1,172 ft. At the latter point it emerges from the solid rock into a detrital deposit lying between the mountain and the power house and is 5.25 ft. in diameter for a distance of 252.7 ft. The upper end is concrete lined for a distance of approximately 200 ft. Below this there was constructed a light sheet metal lining of 3/16-in. boiler plate which was placed and riveted and the space between the steel lining and the granite walls back-filled with 1:3:3 concrete. The internal diameter of the steel lining was 7.5 ft. and the tunnel was driven in approximately circular form 9 ft. in diaemter. The steel was centered in the tunnel and installed in 10-ft. sections. Installation of the steel lining was begun at the lower end just before the pipe tapers down to the diameter of 5.25 ft. At this point a taper section of 1½-in. butt-strap steel pipe was placed in the solid rock. Around this a heavy bulkhead of concrete was constructed and anchored into the bedrock by means of steel rods driven into the sides. Below the taper the penstock is of steel plate constructed to withstand the static pressure without external support and with no concrete envelope.

The rock formation through which the incline tunnel was driven is fractured and broken requiring timbering for the greater part of the incline. The timbers were removed ahead of the steel work, the bedrock cleaned off and the concrete tamped into place without difficulty until a point about 120 ft. below the top was reached. At this point some timbers were removed without bracing the sets above, resulting in a cave-in of the shaft. This section was retimbered with octagon steel sets of 7-in. I-beams, riveted and left in place as the concrete was poured behind the steel lining.

In December, 1908, it was noticed that a stream of water was coming from the portal of the tunnel near the power house. A shut-down was arranged and an inspection disclosed an open seam in the steel lining about 150 ft. in elevation above the power house. An attempt was made to caulk this and make temporary repairs, but due to load conditions it was impossible to shut down long enough to make a permanent repair and in January, 1909, the penstock failed. At the time of failure the plant had been shut down for about 12 hours for tunnel repairs in the upper end of the system. The penstock was full of water which probably backed up in the flow line for a distance of a mile. The only consequent damage done was to the penstock itself.

At the time of failure the water from the pipe came out of the mountain through a cross-cut construction tunnel about 100 ft. above the failure. It is assumed that the water backed up through crevices and fissures in the rock and found relief through this tunnel. Subsequent inspection showed that five sections of the pipe had ruptured where the open seam was discovered in December, 1908. In addition, there were one or two sections which had ruptured internally. These were located at the lower end of the incline near the elbow. It is thought that this lower failure was due to a static head of water on the outside of the steel lining and that this failure occurred some few minutes after the upper failure.

It is thought that the steel lining was taking the entire hydrostatic load and that the concrete lining in setting gradually shrunk from the steel shell leaving a very small space between the concrete and steel.

Repairs made consisted of the construction of a complete new penstock 6 ft. in diameter, built to take the entire static head. The space between the new and the old pipe was back-filled with concrete. Each section of the new pipe was placed on a boring mill in the shops and the end faced off perfectly true. Butt-straps were placed inside and outside of the longitudinal seams and riveted. The round-about straps were outside only. The pipe and butt-straps were drilled and the butt-straps then tapped for patch bolts. Adjoining section was fitted to the first section and the first section shipped to the job, the third section was fitted to the second and the second shipped to the job, etc. On arriving at the job the first section was mounted in place and concreted to within a foot of the top. The next section was mounted in place with the butt-straps held loosely by three or four bolts. The patch bolts then were inserted and screwed tight from the inside. The square heads of the bolts then were chipped off and each patch bolt caulked, the round-about seam being caulked with a special tool.

The new pipe was a very workmanlike job, the inside being perfectly smooth. The repair work required some eight months to complete and has been a very satisfactory installation.

Failure of Pressure Tunnels on Los Angeles Aqueduct—On the Los Angeles aqueduct there were two tunnel failures, one on a special test and one when the water was first turned in. A brief description of each follows:

Jawbone Canyon Test—This tunnel was driven in a porphyry formation which was not very hard and was somewhat shattered with a few clay seams and lines of fracture resulting in smooth slip-planes. It was 305 ft. long, had a depth of cover ranging from 150 to 225 ft., and was lined with 1:4 concrete 10 in. thick and plastered with 1:2 mortar. This tunnel was tested under a theoretical head of 1,100 ft. Lines of rupture developed and the site was abandoned.

Sand Canyon Tunnel—This tunnel was 9 ft. in diameter and lined with a 12-in. thickness of 1:2:4 mix concrete. A diagrammatic profile is shown in Fig. 7. Horizontal runs and the first 150 ft. of incline on the south side were grouted at a pressure of 200 lb. per sq.in. The ends of the steel pipe were covered with concrete for a length of 10 ft. The formation on the north side was hard, massive granite having a cover of 83 ft. at the end of the steel pipe. The rock on the south side was not as sound as at the north side and the pipe was carried in until a cover of 170 ft. was obtained.

The tunnel was filled slowly and after reaching a pressure of 70 lb. it dropped back to 50 lb. Small leaks developed through the rock near the bulkhead in both the north and south ends, the total seepage at all points being about ⅛ sec.-ft. under a 45-lb. pressure.

The full head then was turned in slowly in order to complete the test. Under a 160-lb. pressure a break occurred in the side hill on the north side 80 ft. in elevation above the top of the pipe, about 150 ft. west of the pipe and almost directly opposite the end of the steel pipe. The total leakage was then about 100 sec.-ft. An inspection showed a 3-in. diagonal crack from the bottom of the steel pipe 50 ft. back to the spring line, then a 1-in. crack horizontally for a length of 100 ft., then tapering gradually to nothing, the entire length being 230 ft. The steel pipe had pulled out a distance of 1½ in. owing to a horizontal angle in the pipe line. The blowout occurred in soft decomposed granite rock which showed some evidence of stratification.

A smaller pipe then was placed inside the tunnel extending back until the cover was 170 ft. Upon filling the tunnel again a leak developed on the south side about two-thirds of the way up the slope. An examination showed no cracks in the upper 100 ft., but

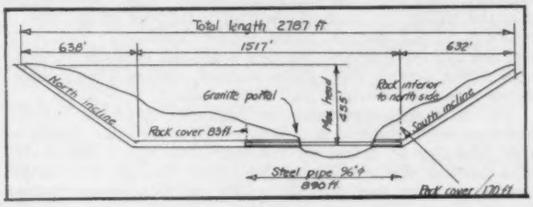


Fig. 7. Profile of Sand Canyon tunnel.

numerous small cracks up to ¼ in. in size, below. There were no cracks in the lower third of the slope.

The next step was to develop final failure, so water was turned in again. One or two sec.-ft. showed at the same place the first day. Slides developed next day and in about half a day 250,000 cu.yd. of overburden was moved between 30 and 50 ft. An inspection of the tunnel showed the concrete to be badly cracked, some fissures 2 in. in width.

The failure was attributed to the following causes:

The cover was not all solid rock although the tunnel was in itself driven entirely in solid granite which contained some fissures.

Shrinkage of the concrete resulted in the formation of small cracks. The water worked up to cracks near the surface under considerable pressure and broke off the top material. Successive ruptures at lower levels followed.

Partial Failure of Ritom Lake Tunnel Lining—The Ritom hydro-electric power station was built by the Swiss Federal Railroads. The pressure tunnel carrying the water from Ritom Lake to the pressure pipe line was filled in May, 1920, and soon was found to be leaking. The tunnel was completely lined with concrete and in places where cavities might be expected behind the concrete, cement grouting was used. Water pressure was 54 lb. per sq.in. at the upper end and 65 lb. at the lower end of the tunnel. The tunnel is 2,800 ft. long, has a grade of 0.007, and is situated about 5,800 ft. above sea level. It parallels the mountain side and has a minimum overburden of 133 ft. The rock formation is rather soft mica schist and micaceous gneiss.

A few days after water was turned in springs appeared on the mountain side and an earth slide started followed by more springs. When the tunnel was emptied the springs at once ceased. Inspection showed the concrete lining to have a great number of very small cracks, for the most part longitudinal. The concrete seemed to be of good construction and it was concluded by the investigating committee that the formation of the cracks possibly was due to a certain yielding of the rock. To avoid a long outage of the plant the cracks were sealed and the tunnel again put in service under reduced pressure. It was found that as long as the pressure at the lower end of the tunnel was kept under 14 lb. per sq.in. no further leakage occurred.

Leakage on Rondout Siphon of Catskill Aqueduct—The Rondout pressure tunnel of the Catskill aqueduct is 23,608 ft. long, has a circular section 14 deg. 6 in. in diameter and an original concrete lining of 20 in. thickness. It was completed in 1912.

When the tunnel was filled to within 58 ft. of the hydraulic gradient for the first test a leakage of 2,600 gal. per min. developed. The tube was unwatered immediately and cracks were discovered In the lining near Shaft 4 where mud seams had been encountered during the driving of the bore. The main body of the concrete lining appeared to be intact and where ruptured the evidence was that the upper half simply had been lifted off the lower half by the heavy hydrostatic pressure. The unbalanced hydrostatic pressure at the time of stopping the test probably was more than 100 ft. In sandstone formation the lining showed a crack of 1/16 to ⅛ in. at the spring-line of the arch and in the limestone formation the crack was as much as 3/16 in. with diagonal shear cracks. Investigation showed that these sections had been well grouted. It seemed probable that in the limestone there had been a general movemnt of the rock, and in the sandstone the rock simply had been compressed a little in taking up the load.

The tunnel was repaired by lining the ruptured sections with 15-in. channels bent to a radius of 2 in. less than the original radius of the tunnel. The channels were riveted together and caulked, a 7½-in. lining of concrete poured inside the steel and the 2-in. annular space between the steel and original concrete surface grouted. After the 2-in. space was grouted at pressures of from 20 to 30 lb. the fissures in the rocks were grouted at pressures as high as 300 lb. per sq.in.

After this repairing work a test showed the leakage to have been cut to about 850 gal. per min., which was considered highly satisfactory as against an estimated leakage of 3,500 gal. per min. under full head before repairing.

Partial Failure of Tunnel No. 10 Lining—In December, 1922, a severe storm caused a line outage that necessitated Wise power house being disconnected from the rest of the system of the Pacific Gas and Electric Company. In order to get rid of the water the relief valve at the power house was opened. It was known from gage readings taken on the penstock line during similar conditions that had occurred previous to this time that this discharge through the relief valve set up pressure surges in the penstock which produced pressure at the Ventura meter at the lower portal of Tunnel No. 10 100 per cent greater than the normal static pressure.

Tunnel No. 10 is in the penstock line 6,700 ft. above the power house. At that particular time failure occurred in the tunnel at a point about 10 ft. above the point where the steel pipe ends inside the lower portal. About 20 sq.ft. of concrete lining was torn out of the top of the tunnel and a crater formed through the overburden which was about 15 ft. deep at this point. Through this opening the water discharged for several hours until turned out of the canal above.

Examination showed that there had been no rupture of the steel reinforcing, but that the concrete had been forced out between the bars. The concrete around the hole was broken and very soft and crumbly, so that it seemed that poor, porous concrete had allowed leakage that prevented the overburden from acting with the lining in resisting the internal pressure. A heavy leakage at the surface at the lower portal had been noted before this failure. This excess rise in pressure was not foreseen or allowed for in the original design of the tunnel lining. Repair was made by removing old concrete down to steel for a length of tunnel, placing additional bars, replacing concrete, and waterproofing with gunite.

Partial Lining Failure of Caribou Tunnel No. 2—Caribou tunnel No. 2 of the Great Western Power Company was designed and constructed under the assumption that the country rock was watertight and that water escaping through weepers left in the tunnel lining would fill the void between tunnel lining and rock-bore and thereby equalize inside and outside pressures. The tunnel was driven through an ever-changing formation. Lava was encountered at the upper end, then hard shale, soft shale, swelling ground, and at the lower end of the tunnel a blocky serpentine.

The overbreakage along the back of the tunnel timbers ranged from 1 to 4 ft. Concrete was not reinforced to withstand internal pressure and the outside lagging in the arch was not removed to permit the concrete to fill the void between the rock bore and the tunnel timbers. The tunnel was placed in operation in 1921 and no trouble was experienced. The Butt Valley dam was completed in the spring of 1924, and an additional head of approximately 50 ft. placed on the tunnel. Leakage was first detected in July of the same year and a month later had reached serious proportions.

Inspection disclosed cracks along the sides in the upper quarter of the concrete arch varying in size from a hair line to 1½ in. in width, while in two sections in different formations and for a distance of about 100 ft. each the concrete lining was badly shattered from the spring-line over the entire arch.

Rupture occurred in the lava and serpentine formation and in the shale and swelling ground adjacent to the lava and serpentine contacts. The shale and sepentine were watertight and breakage in these sections was due to water coursing along the back of the tunnel lining and escaping through the water courses at the contacts. Rupture of the tunnel lining would not have occurred except in the lava and serpentine regions if cut-off barriers had been placed near the contacts.

Repairs were started in the spring of 1925. The tunnel flow was regulated at the intake gate and the governors of the Caribou power house set for a load that would not necessitate a water flow above the spring-line. Existing adits were utilized and additional connections driven to tap the sections that were to be repaired. Low, narrow drifts were driven along the back of the tunnel lining points 10 or 15 ft. beyond the damaged sections. The sides then were excavated to a point near the spring-line (where the concrete was found to be tight against the country rock) and 5-ft. cut-off rings were excavated at the extremities of the main excavations. Several 8-in. pipes were inserted along the back of the tunnel beyond the cut-off rings and the opening between tunnel lining and rock corked to prevent concrete flowing along the back of the tunnel and blocking the pipes. These pipes then were extended to the surface to be used in the subsequent hydraulicking. Bulkheads were erected at intervals of 30 ft., and the excavated area filled with a lean mix concrete by concrete guns. To insure a good seal, 3-in. grout pipes were left in the back at 15-ft. intervals and grouting proceeded as the bulkheaded sections were completed. Concrete plugs and cut-off barriers were poured at the junction of each working connection and the tunnel.

Hydraulic pits of suitable material were selected near the portals of the adits and material screened with a ⅜-in. mesh was pumped under 150-lb. maximum pressure through the feeder pipes left in the various headings. The success of this operation far exceeded all expectations, as it was feared that plugging would result within a comparatively short distance from the ends of the pipes. However in each case the material flowed freely from heading to heading as much as 1,000 lineal ft. A measurement was kept of the amount of hydraulic material pumped underground and upon completion of the work it was determined that 1.1 cu.yd. per lineal ft. had been deposited along the tunnel bore.

Hydraulicking was completed in October, 1925, and the tunnel again placed under pressure. A careful check disclosed no apparent leakage and the tunnel has been under successful operation since.

Power House Cranes*

This report is intended to cover cranes used in substations as well as power houses because the usage given each is very much alike.

It is believed that, in the past, cranes of unnecessarily expensive design have been installed in power houses and substations. In this service the infrequent use does not necessitate the allowance for wear and the exceptionally high factors of safety which usually are incorporated in factory or mill cranes. For this reason an expression of opinion on crane design from the various member companies and local crane manufacturers has been secured and forms the substance of this report. The construction which, it is believed, will be satisfactory under the service required has been recommended herein and should permit economies of construction with due regard for safety.

It is not intended that manufacturers should not continue to submit proposals on their standard designs, but rather that all concerned may be familiar with the requirements and the type of construction acceptable for cranes used in power houses and substations.

Economic Factors Affecting Selection of One or Two Crane Units for Maximum Lift

In general it may be said that for maximum lifts of less than 75 tons a single crane will prove economical. For greater loads an economic study should be made of all the items involved and the decision of installing one or two crane units should be based upon the results of that study. Individual preferences no doubt may lean either to one or two-unit installations, but the fact remains that either will operate and has operated satisfactorily; cost is the proper basis of comparison.

A two-unit installation requires two operators for lifting loads above the capacity of either and requires careful co-ordination between the two units when handling such loads. As has been previously stated, however, many power houses are equipped with two units and no difficulty in operating simultaneously has been reported. The cost of two-man operation need not be considered as loads requiring a capacity greater than that of one crane are seldom lifted and then for only a brief interval. It is highly inadvisable to hook two cranes together electrically for one-man operation as the difference in motor characteristics makes accurate control impossible.

The cost of two cranes of half maximum load capacity usually is greater than the cost of a single crane of maximum load capacity, particularly if an equalizer beam is required. The headroom requirements of the individual half capacity cranes are less than those of the single full-load crane, but (if used) the equalizing beam headroom requirements may throw the advantage of lower headroom to the single-crane unit. Headroom actually may be gained by the use of an equalizing beam, however, if the load is such that it can extend up through the equalizer beam, as in the case of the shaft of a vertical waterwheel unit.

The great advantage which the two-unit crane installation possesses is the distribution of loading over a greater length of the crane girders with a resultant saving in the weight of the girders and columns and a saving in the concrete footings of the columns. An additional advantage in erection is gained by having two cranes available at a time when the demand for crane service is at its greatest.

An analysis of the above factors should be made for each installation until the costs of one or two-unit installations are shown to be constantly favoring one or the other, which the wide range of sentiment expressed indicates has not been definitely proved to date.

Methods of Reducing Headroom Requirements:

The necessity of obtaining cranes with headroom requirements reduced to an absolute minimum cannot be overstressed. The distances between the high point of the hook and the top of the trolleys of competing cranes should be studied carefully when comparing bids, and the cost of raising the building the height necessary to house the cranes of greater headroom requirements added to the purchase price of

* Report of subcommittee of hydraulic power committee—C. deWitt, chairman. C. M. Mardel, J. F. Partridge, C. P. Rhine, H. D. Root, E. J. Waugh.

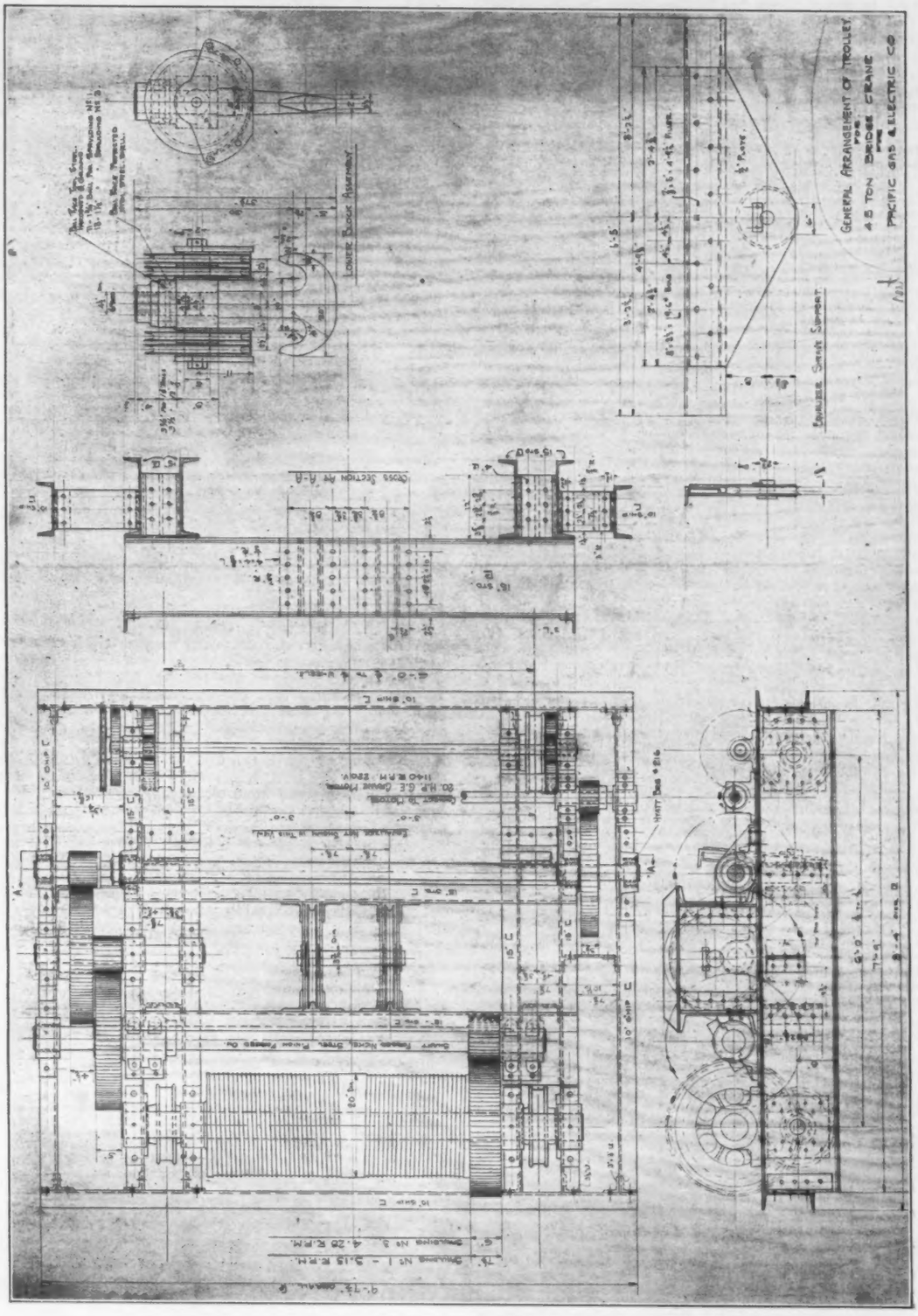


Fig. 1. Trolley layout showing method of placing gearing to reduce headroom requirements.

such cranes. It is recommended here that negotiations for the purchase of crane requirements should be started early in the development of power house or substation designs so that full advantage of headroom saving may be taken in the design of the building.

It seldom is necessary to bring power-house cranes to the extreme ends of the buildings, so it often is possible to spread the train of reduction gearing laterally instead of vertically without exceeding the requirements of lateral clearance. An example of this type of construction is shown in Fig. 1. A saving of a foot or two in vertical clearance may be obtained by constructing the cross-head of the hook and the sheave pin in one unit as shown in Fig. 2. Considerable headroom may be saved for the maximum lift of vertical-shaft machines by looping the cable on a pin instead of using a hook and slings.

The inclusion of worm-gear reduction in the hoisting mechanism should make a reduction in headroom required possible, as well as make the entire mechanism more compact. However, no installations of this type have been brought to light on the Pacific Coast.

Speed of Operation

Power-house cranes are operated very infrequently and therefore do not require great rapidity of motion as the time lost in slow operation is negligible. The precision with which the maximum loads must be moved and the safety of those valuable loads demand that very moderate speeds be adopted for the various motions. The lower speeds also permit economies in design of the mechanism and the inclusion of smaller impact factors in the design of the crane and supporting structure.

The following table gives the range of present practice in the systems of Pacific Coast power companies:

TABLE I—Speed of Operation in ft. per min.

Capacity in Tons	Main Hoist	Auxiliary Hoist	Trolley	Bridge
30	5–7.5	20–30	20–75	50–150
40	5–7.5	20–30	20–75	50–150
50	5–7.5	20–30	20–75	50–150
60	5–7.5	20–30	20–75	50–150
75	4–7.5	15–30	20–75	40–150
100	4–7.0	10–30	20–60	40–120
150	4–7.0	10–30	20–50	40–100

It is believed that some attempt to standardize the various speeds of operation for power-house cranes should be made, and to that end a table of recommended speeds is given below:

TABLE II—Speed of Operation in ft. per min.

Capacity in Tons	Main Hoist	Auxiliary Hoist	Trolley	Bridge
30	5	20	20	40
40	5	20	20	40
50	5	20	20	40
60	5	20	20	40
75	4	20	20	40
100	4	20	20	40
150	4	20	20	40

Impact Factors

Motor Operation.—The bridge girders should be designed with an additional allowance of 25 per cent of the suspended load for impact. The lateral load on the bridge girders, due to starting and stopping, should be taken at 10 per cent of the vertical load and divided between the top flanges of the two bridge girders. The longitudinal and lateral thrusts on the crane runway girders on each side of the building should be taken at 10 per cent of the wheel concentrations. The vertical load on the runway girders should include a 25 per cent impact factor.

Hand Operation.—It is not believed that any crane motion operated by hand needs an impact factor added to the static load. The impact factors above should be added to the normal loadings and the combined stresses in the material should not exceed the maximum allowable specified, which has been increased in recent years by the acceptance of the A. I. S. C. code for structural steel.

Motor Type Torque and Horsepower Requirements

In present-day practice the a. c. slip-ring type of induction motor is in almost universal use for crane work. Starting or pull-out torques from 2 to 2½ times the full-load running torque for the main hoist are recommended. Unnecessary stressing of the mechanism and supporting structure may result due to careless operation, if torques in excess of the above are used. Another advantage of lower starting and pull-out torques lies in the fact that excessive loads cannot be lifted, which automatically safeguards the equipment from undue loading. For the short periods that power-house cranes are called upon to operate, serious injury seldom will result from overloading. However, overloading should be avoided as a general practice.

All parts of the crane and supporting framework should be able to resist loadings due to the development of the full pull-out torque of the motor without exceeding the elastic limit of any of the parts thereof.

Crane motors should have frames, covers and bearings split to facilitate the removal of armatures or rotors. Separate motors should be used for each motion of the crane to avoid the locking of gears and clutches otherwise necessary. The size of motors required may be approximated for spur gear reductions by allowing 1 hp. for each 10 ft.-tons per minute of hoisting effort. Limit switches should be fitted to control the upper limit of all hoisting motions and for the lower limit where the hook does not actually reach the floor or the bottom of pits, but usually are not considered necessary on the horizontal motions.

Bridge and Trolley Structural Design

It is recommended that American Institute of Steel Construction stresses be adopted for the bridge and trolley structural design with impact factors added to the direct loading as already outlined. The design should be checked against the full pull-out load of the motor to see that the elastic limit is not exceeded at any point of the structure.

Fabrication of bridges and trolleys by means of arc welding is suggested by one power company, but no installations of welded cranes are in use on the Pacific Coast. This type of construction is becoming increasingly popular, however, and should be duly investigated as to costs and strength and recommendations should be embodied in later serial reports on this subject.

Deflection of the bridge under maximum load at the center of the span should not exceed 0.01 in. per ft. of span. The ratio of wheelbase to span is an important consideration in the design of cranes and should not be less than one-fifth. Bridge walks should be placed under rather than over the bridge propelling line shaft to facilitate inspection, lubrication and repair of line shaft bearings.

Structural bridge-ends, when properly designed, are entirely satisfactory and in general should be cheaper than a corresponding cast steel type, especially when the crane is designed for a particular installation and manufacturer's standards cannot be used.

Rail Weights

The vertical loading on both the bridge and crane runway rails ordinarily will not cause excessive stresses in rails lighter than those generally considered as standard due to the fact that the rails are continuously supported and are not subjected to the shock of high-speed rolling equipment. The side thrust on high-speed cranes due to starting and stopping may necessitate the use of rails with thick webs, but the slow speeds of the average power-house crane should not produce alarming stresses in lighter rails. Cranes with hand operation of bridge and trolley undoubtedly can be equipped with rails far lighter than generally in use now.

To arrive at reasonable weights of rails, the following formula is suggested:

$$\frac{\text{Rail weight in lb. (A. S. C. E. std.)}}{\text{Single wheel concentration in lb.}} = \frac{1}{110}$$

with minimum rail weight of 40 lb. (A.S.C.E. std.).

Hook Design

Ball-bearing, swivel-head hooks of the single piece twin or "sister" type are believed to be the best suited for power-house uses, except for cranes of 30-ton capacity or less. The ball races should be grooved, hardened and ground, and the balls should be of chrome alloy steel manufactured by a ball-bearing concern of reputation. The load on 1-in. diameter balls should not exceed 4,000 lb., 1¼-in. balls 5,500 lb., and 1½-in. balls 7,000 lb. It must be borne in mind that these loadings are permissible only for the limited use to which power-house cranes are put.

Tension on the stem of the hook should be limited to 10,000 lb. per sq. in. and the combined tensile and bending stresses in the hook proper limited to 20,000 lb. per sq. in.

Wire Rope

Hoisting rope preferably should be made of 6/19 plough steel, 8/19 or 6/37 extra-pliable plough-steel hoisting rope with a hemp center, allowing a factor of safety of 8 in figuring the size of the rope. The attachments of the rope ends to the drum should be such that if all the rope were unwound the attachment would be strong enough to carry the load. The number of plies permissible may be greater than in a factory crane as the sheaves, drums, shaftings and boxes may be materially reduced and the wear on the rope will not be excessive owing to the infrequent use of the crane.

Drums and Sheaves

All sheaves should be made of cast steel and drums of cast iron fitted with bronze bushings and steel pins. The pitch diameters should not be less than 24 times the hoisting rope diameters. Sheaves and drums should be properly grooved for the rope used, drum grooves being cut from solid stock, the grooves being machined right and left hand to equalize the load on the drum. The main hoisting gear should be bolted to the drum with a flanged connection with machine fitted bolts in reamed holes.

Grooves should be provided on the drum to take care of the full amount of the lift specified, and leave a surplus of 1½ wraps on the drum when the hook is in its lowest position.

Gearing

All large gears should be made of cast steel with cut teeth, and pinions less than 8 in. in diameter should be made of forged steel. Spur gears for bridge and trolley travel may be made of cast iron. No overhanging gears on the hoisting mechanism or bridge travel should be permitted, except possibly the motor pinion.

The teeth of gears should be of the 15-deg. involute type except the main hoisting gear which should have 20-deg. involute teeth. Stub teeth may be used where greater strength is necessary. The Lewis formula for calculating the strength of gears is considered the best:

$W = S\ p\ f\ y$ where W = working load
S = safe working stress
p = circular pitch
f = width of face
y = constant depending upon the shape and number of teeth; values are tabulated in machinery handbooks.

For steel gears, S may range from 10,000 lb. at 100 ft. per min. to 3,000 lb. at 1,200 ft. per min. These values will allow for full pull-out load on the motor without exceeding the elastic limit of the material in the gears.

Where properly machined and treated worm gearing of bronze and alloy steel is used some economy may be obtained by using worm gearing for the first reduction from the motor. The worm gear should be made non-reversible to add to the safety when handling valuable loads.

Renewable bronze bushed bearings are considered to be the most suitable for crane use. Ball and roller bearings are believed to be unnecessarily expensive except for worm gear drive. Babbitted bearings are not capable of withstanding the shocks of crane service except where the bearing load is low.

Axles and Pins

Axles and pins of the fixed type are preferred, with the wheels or sheaves bushed with renewable split bronze bushings and running loose on the axles. Bridge and trolley wheels for hand-operated motion should be equipped with roller bearings. The pressure type of lubrication is believed to be the best for the usual conditions of service for slow and medium-speed bearings and oil-ring lubrication for high-speed bearings.

A high quality of steel shafting should be used for pins or axles, taking bending and mild steel shafting for the bridge operation shaft. The bending stresses combined with any torsional stresses in pins and axles should not exceed 8,000 lb. per sq-in. under full-load torque. Normal torsional stresses in the bridge operation shaft should not exceed 4,000 lb. per sq.in. The distance between bearings on shafting subject to no bending except its own weight is fixed by limiting the permissible deflection to 1/80 in. per ft. of length.

The area of plain bearings should be such that the load in lb. per sq.in. times the square-root of the rubbing velocity in ft. per sec. does not exceed 900. Maximum allowable bearing pressure in any case should not exceed 1,500 lb. per sq.in. Allowable bearing pressure for

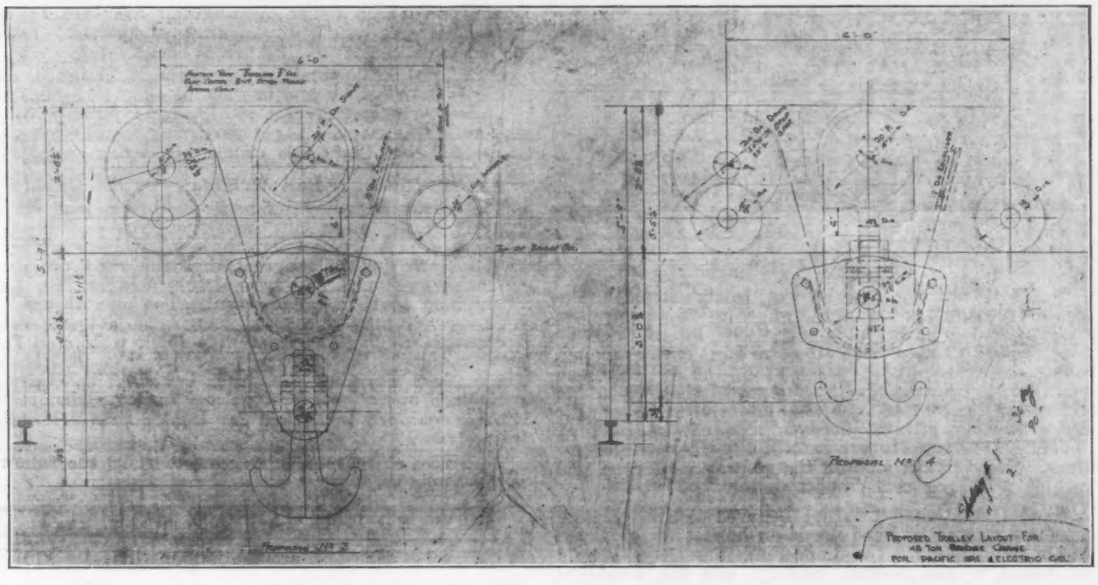


Fig. 2. Hook cross-head and sheave pin designed for reducing headroom requirements.

the fixed portion of the pin in the steel frame should not exceed 16,000 lb. per sq.in.

The gear which operates the bridge travel countershaft should be placed at or near the center of the span to assist in equalizing the torsional deflection at each drive wheel. The countershaft should be designed to take any inequality of torsional load due to the trolley and suspended load being at one end of the bridge.

Brakes

Hoisting motions should be equipped with solenoid brakes capable of holding the full load suspended when the power is off. Series-wound d.c. motor operated equipment should be supplied with dynamic brakes to prevent excessive speeds when operated under light loads. For control of the load when lowering, a dynamic or mechanical automatic friction brake should be provided and so arranged that the motor must be operated in a lowering direction in order to lower the load.

A foot brake for controlling the bridge motion is very desirable, but brakes on the trolley motion are not used ordinarily. Non-reversing worm gearing would obviate the necessity of brakes on any of the motions of the crane.

Wheels

The number of wheels to be used per crane side depends upon the capacity of the crane, the span of the crane and the span of the crane girders. To reduce the concentration of loading on the crane runway girder from large capacity cranes a four-wheel bridge-end usually is desirable. A greater ratio of wheel-base to crane-span is obtained at the same time without increasing materially the weight of the bridge-ends. As this ratio never should be less than 1/5, it may be seen that for long crane spans this construction is particularly desirable.

Where the spacing of crane columns is comparatively large a large spread of the crane-wheel loading will reduce the maximum loading per column and result in a saving in both the column and footing as well as in the runway girders. For smaller capacity cranes (50 tons or less) 2-wheel bridge-ends usually are suitable, particularly for an installation where the crane span and crane column spacing are comparatively small.

All crane wheels should be double flanged with shoes to prevent accidents. Cast steel is the cheapest construction material and should be satisfactory although no objection to chilled cast iron or rolled steel wheels can be seen. Operating gears should be bolted to the wheels without reliance upon keys. Wheels should be ground or machined to uniform diameter properly to fit the rail head used. Side clearance to allow for inequalities in the span between rails should not exceed ⅜ in. per side.

Crane wheels of cast steel shsould be so proportioned that the maximum wheel load in pounds will not exceed 1,000 times the wheel diameter times the width of rail head used (both in inches). Accurate alignment of the wheels at the bridge-ends is absolutely necessary to prevent binding on the flanges.

Gear Guards

Gear guards of sheet metal held by brackets are ample for power-house cranes. The cost of cast iron covers totally enclosing gears is not justified for this type of crane. All gears should be guarded and gear guards should be made in conformity with the rulings of the Industrial Accident Commission, or similar body of the state where the crane is installed.

Worm gears, where used, owing to the lubrication requirements, should run in an oil bath. This requires a complete enclosure for the worm and worm wheel. All sheaves should be guarded to prevent lifting ropes from accidentally leaving the grooves.

Electrical Pick-up Contact

The fixed trolley wire and spring mounted trolley wheel type of electrical pick-up contacts are preferred for the bridge motion. This construction is cheaper than the type having trolley wire hung on flexible hangers and rigidly attached trolley wheels. The sleeve type is not desirable for the bridge motion.

For the trolley motion, sleeve pick-ups are satisfactory unless the span is unusually large, and are cheaper than any other type.

Control of Hoist

Control of the crane motions from a cage is believed to be desirable for large capacity cranes. For small cranes motor hoists and hand-operated bridge and trolley motions are suitable and the pendant type of control may be used to advantage. Cranes of 20 tons capacity or less may be entirely hand-operated.

Operating conditions must be taken into consideration in specifying the type of control and for that reason the matter cannot be arbitrarily decided. The floor pendant-type of control is cheapest and where suitable should be used.

Maintenance

It is not considered necessary to carry spare parts for the cranes of the average power house as the infrequent usage given them should permit very long life with ordinary attention. In lieu of stocking spare parts it may be desirable to have on file details of the replaceable parts of the crane so that replacements may be obtained with minimum delay. Such files should be of great importance where the cranes are not of local manufacture and the delay incident to obtaining new parts from a great distance would be vital.

Cranes should be inspected thoroughly at least once a year and always just prior to the undertaking of heavy lifts. If cranes are standing absolutely idle it is desirable to operate the cranes periodically even without load through the full travel of all motions to check the workability of the electrical devices and to keep the mechanism in good running order. It is advisable to have at least two roof trusses capable of handling parts of the cranes for erection and dismantling purposes.

Penstock Painting*

From the various reports submitted it is very evident that there are two very urgent reasons for painting penstocks to prevent corrosion both inside and out, and to save friction loss due to corrosion.

Corrision will take place both outside and inside. The outside can be cared for the same as any other metal surface and in most cases, being available for inspection, con be maintained easily. But the interior rarely is available for inspection and still less frequently available for proper maintenance. Therefore it is important that the first treatment be first-class in material and workmanship.

The loss in strength due to corrosion although small, is not insignificant. For instance one of the reporting members has a penstock 54 in. in diameter and 4,359 ft. long from which there was removed about 23 tons of rust "barnacles."

It has been ascertained from numerous tests that in conduits carrying flowing water the rust deposit represents one-third of the total corrosion, the other two-thirds being carried off in solution. The same tests also have proved that one-third of the total weight of the corrosion equals the amount of metal actually broken down. Therefore the weight of corrosive solids left in a flowing conduit approximates the weight of metal removed by corrosion.

In this case it is equal to 0.7464 lb. per sq.ft., equivalent to a thickness of 0.018 in. This loss has taken place during a period of a few years and while not very serious it is somewhat disturbing.

As to loss of head by friction, if the interior of the conduit is allowed to become corroded and encrusted, it is interesting to note that in the case in question tests "before" and "after" show an improvement in the carrying capacity of this pestock which amounted to 112 kw. when conveying 110 sec.-ft. and 262 kw. when conveying 130 sec.-ft. This at 65 per cent load factor would represent respectively 635,000 kw.-hr. and 1,110,000 kw.-hr. annually.

It is of great benefit, therefore, to keep the interior of penstocks well protected to obviate loss of head due to rough interior.

Corrosion

Corrosion and its prevention are subjects that have been studied very intensively for many, many years. The biblography on these subjects is vast. Nearly every engineering society of the world has had committees at various times studying it.

To try to peruse all this vast accumulation of information is a life task. Mr. Speller already has de-

* Report of subcommittee of hydraulic power committee—C. M. Mardel, chairman. C. L. Davis, J. W. Jourdan, Hector Keesling, J. F. Partridge, E. D. Sismey.

voted many years to a study of the subject and has accumulated the best information in his book "Corrosion —Causes and Prevention," which may be regarded as the best and latest authority on the subject.

Quoting from this book:

Corrosion may be broadly defined as the chemical action of certain external agencies on metals which causes their deterioration or destruction. This metal tends to revert to more stable combinations of which the metal ores, as found in nature, are familiar examples.

Important Established Facts Regarding Corrosion

1. It is well known that iron will not corrode at normal temperatures in the entire absence of moisture.

2. The presence of oxygen also is essential if appreciable corrosion is to take place in ordinary water. Oxygen and water alone will cause corrosion even in the absence of carbon dioxide or other acids. In natural water, corrosion is almost directly proportional to oxygen concentration, if other factors do not change. Oxygen also accelerates the corrosion of iron in dilute acid solutions.

3. Corrosion in acid is much more rapid than in neutral solutions, and the latter is more rapid than corrosion in alkaline solutions.

4. Hydrogen gas usually is evolved from the surface of the metal during corrosion in acid solutions, but the evolution is very much less in neutral and alkaline solutions.

5. The products of corrosion include mainly black or green ferrous rust which forms next to the metal, and reddish-brown ferric rust which forms the outer layer, with graded mixtures of the two in between. When iron corrodes in the atmosphere the amount of ferrous rust is small, but when formed under water, the ferrous rust often amounts to as much as one-third of the corrosion products.

6. In corrosion in natural water the precipitated rust usually carries down some calcium, magnesium, and siliceous compounds together with other insoluble material from the water. These substances have considerable influence on the structure and density of the rust coating on the metal surface. If the rust coating is loose and non-adherent, under ordinary conditions the rate of corrosion may be accelerated locally, but on the other hand, if it is unformly dense and adherent it may cut down the rate of corrosion very considerably.

7. In most cases the initial rate of corrosion is much greater than the rate after a short period of time. This is particularly noticeable in alkaline solutions. As an exception, however, it should be noted that the initial rate of corrosion of a highly polished metal surface is abnormally low.

8. Corrosion is increased in dilute solutions of many neutral salts, but is decreased in more concentrated solutions, other things being equal.

9. In natural waters the rate of corrosion generally tends to increase with increase in the velocity of motion of the water over the metal surface.

10. Composition of the iron, within the ordinary variations found commercially, has little or no effect on corrosion under water, but sometimes it has a marked effect in atmospheric and acid corrosion. From the standpoint of corrosion homogeneity of metal is not usually so important as external conditions.

11. The condition of the metal surface in submerged corrosion may not affect the total corrosion, although it may have a marked tendency to localize the action.

12. Corrosion of iron is rarely uniform over the entire surface. Dissimilar metals in contact with each other, or with electrically conductive material in solution, tend to accelerate corrosion locally. This action is indicated by an electric current which flows through the solution from the more corrodible to the less corrodible material, i.e., from the anode to the cathode.

13. Variation in concentration or in composition of solutions in contact with a metal tends to localize corrosion at certain areas of the surface (i.e., accelerate it) and retard the action at others. When a portion of the metal in solution is protected from diffusion of oxygen it becomes anodic to other areas which are in contact with a solution richer in oxygen, i.e., corrosion is more active at such protected areas. The smaller the anodic areas with relation to the associated cathodic areas, the greater is the rate of corrosion at the anodic points and the greater the tendency for the formation of small holes or pits.

14. The polarity of a certain area is often reversed during the progress of natural corrosion.

In addition to the foregoing, many other points have been determined and further significant facts are constantly being developed as a result of the wide interest in this subject.

Non-Technical Statement of the Electro-Chemical Theory

The Electro-Chemical Theory now is generally accepted as the one which best explains the preceding established facts. Before discussing the variables which may play a fundamental part in the corrosion reactions, a non-technical explanation will be given in popular terms.

Iron, like all other elements, has a definite, inherent tendency to go into solution when placed in contact with water. Iron, however, can enter solution only by displacing some other element already in solution. For instance, a piece of iron placed in copper sulphate goes into solution, but at the same time copper is plated out and appears on the surface of the iron. In the ordinary case of iron immersed in water, hydrogen is the element plated out. This hydrogen gathers on the surface of the iron in the form of a thin, invisible film.

The presence of this film tends to obstruct or congest the progress of the reaction by insulating the metal from the solution. This interference may become so effective in natural waters as to stop corrosion altogether. Thus, the first stage of corrosion comes to a stop so quickly that no appreciable damage is done to the metal if the process goes no further.

In order that corrosion may proceed, the film of hydrogen must be removed. This can happen in two ways: either it may combine with oxygen in solution to form water, or it may escape as gaseous hydrogen.

Dissolved oxgyen usually is present in water solutions, and removes the hydrogen film by reacting with it to form water. The process then is free to continue, that is to say, more iron can go into solution, more hydrogen can plate out, and the process can continue at a rate determined by the speed with which the oxygen removes the hydrogen. This is the second stage of corrosion and accounts for the continuance of the process in the great majority of cases.

In acids the same reaction takes place. In addition to this, however, the tendency for hydrogen to plate out is much greater and so much of it gathers on the metal surface that it is forced off in the form of hydrogen gas bubbles. Corrosion, therefore, is proportionately more rapid in acid solutions than in natural waters.

Ordinarily the iron which goes into solution is immediately thrown down as rust. After a time the rust together with insoluble material from the water may form a protective coating on the surface of the metal which interferes with the corrosion reactions by insulating the metal from the solution.

Factors Influencing Rate of Corrosion

In order to explain the facts cited previously it is necessary to consider many factors which influence the rate of corrosion. It is well known that the presence of oxygen is one of the most important of these factors. The corrosion rate in most natural waters is determined by the rate at which dissolved oxygen reaches the metal surface, which in turn is determined by many factors, such as the rate of solution of gaseous oxygen, the rate of diffusion of dissolved oxygen concentration of the water, the temperature at which the corrosion occurs, the pressure and humidity of the air above the corroding solution, the velocity of motion of the corroding solution, the presence and nature of surface films and coatings on the metal, the concentration of other dissolved substances, the viscosity of the corroding solution, the depth of immersion of the metal, and the area of the corroding solution exposed to the air.

Having briefly outlined the causes and action of corrosion, what step can be taken to present, or at least retard its damaging effects? Consider first the process of manufacture of the metal. At present the only alloy used commercially in the production of large quantities of metal, such as used in penstocks, is copper.

Mr. Speller has this to say on copper:

Influence of copper alloy on underground corrosion has been investigated less than the other classes so that fewer data are available as to the influence of copper or other such elements on corrodibility. In general, like corrosion under water, it appears that the effect of copper is very much less than in the atmosphere.

An extensive soil test now is in progress under the supervision of the United States Bureau of Standards. This includes copper-bearing steel as well as most of the well-known commercial types of iron and steel. The first set of test pieces has been removed after one to two years' exposure and the corrosion has been measured. At present, as far as it is possible to judge from this test, the presence of copper under soil conditions has no very marked influence on either the total amount or the localization of corrosion.

Summary of the Effect of Copper

The addition of from 0.10 to 0.25 per cent copper to normal open-hearth or bessemer steel is decidedly beneficial when the metal is exposed without protection to wet and dry weather conditions. The same probably is true in a large measure when the metal is painted or coated. The maximum effect is obtained at about 0.15 per cent with 0.05 per cent sulphur contents. As a rule the addition of copper to steel appears to have no decided influence one way or the other when the metal is exposed under water, in the soil, or in places where the air does not have free access. It should be pointed out, however, that there are many varieties of soil and water, and that relatively few tests have as yet been made in such media, compared with the more complete experience with copper steel in the atmosphere. Under atmospheric conditions the effect of copper is much more marked than is the purity of iron or steel.

More thorough investigation and study is required before the variable influence of copper is subaqueous and atmospheric corrosion can be explained satisfactorily. The advantage of copper-bearing steel, however, has been demonstrated satisfactorily under atmospheric conditions and in certain kinds of salt water and a considerable amount of this material now is being used for construction which is exposed to such conditions. It has been estimated that in 1923 approximately 500,000 tons of copper-bearing steel were made in the United States.

The surface of metal has much to do with corrosion. Highly polished surfaces resist corrosion. This is impractical in penstock manufacture.

We will now take up the subjects of paints and their application.

Preparation and Protection of the Surface

Irrespective of what coating is contemplated, the preparation of the surface to receive it must be properly done. This perhaps is the most important factor in corrosion prevention and no matter how good the paint or coating if there is a poorly prepared surface the results will be unsatisfactory.

The American Society for Testing Materials has been carrying on experiments on a set of plates at Altoona, Pa., since 1927. These data are shown in the following table, results up to October, 1925. The old plates were cut from an old steel Gondola car. From these tests there is no doubt that sand-blasing is the best method of preparing the surface. It is interesting to note that test No. 4, sand blasted and heated to 225 deg. F., shows poor results. These test plates all were exposed to the atmosphere. It may be assumed that the results would be relatively the same for under-water conditions.

It is very evident that one of the most important factors in the protection of any metal from corrosion is that the application of the paint or protective film be made in such a thorough manner that a perfect bond is made over all the surface. One of the chief hin-

TABLE I—Tests on Preparation of Metal Surfaces—Samples set out —1917, American Society Testing Materials, Committee D-I, Sub. 14.

Sample No.	Description of Preparation	Per cent condition at various dates—100 per cent perfect Nov. 1924	Feb. 1925	Oct. 1925
	New Plates.			
1	Surface cleaned, mill scale intact, painted in warm dry room	75	20	10
2	Mill scale broken, some rust, hand cleaned, painted in warm dry room	85	40	25
3	Sand blasted, painted immediately in warm dry room	95–90	85	80
4	Sand blasted, heated in oven to 225 deg. F., then painted	90–86	65	35
5	Sand blasted, placed in cool damp room for 40 min., then painted	95–90	87	84
6	Sand blasted, placed outdoors at 25 to 27 deg. F., and painted there	90–83	85	84
7	Sand blasted, exposed outdoors for 7 days, painted over rust in warm dry room	90–88	70	50
	Old Plates			
12	Cleaned with brush only	78	85	82
13	Cleaned with Benzine, scraped and wire-brushed	80	70	68
14	Benzine applied over rust spots and burned off with torch, scraped and wire-brushed	85	80	80
15	Sand blasted	86	75	73

Analysis of Plates

	New 1-7	Old 12-15
Carbon	0.107	0.134
Manganese	0.420	0.420
Silicon	0.008	0.009
Phosphorus	0.008	0.015
Sulphur	0.032	0.037
Copper	0.031	0.031

All plates were painted with a paint made from a paste consisting of:
105 lbs. red oxide of iron — 10 lbs. whiting (X. G.)
100 lbs ochre (B. F.) — 208 lbs. silica
141 lbs. raw linseed oil
mixed 32 lbs. of above paste with 8.5 lbs. of linseed oil and 3 lbs. of Kauri gum Japan.

The test still is in progress.

drances to obtaining this bond is mill-scale. Sand-blasting is probably the most effective means that is practical to use in penstock work, any pickling process being impractical. There is no doubt that one of the chief causes for the varied results obtained by apparently similar paints is due to application methods and conditions.

Application

Paint should be applied to a dry surface. Moisture on the metal will tend not only to cause corrosion underneath the paint, but will prevent the paint from adhering to the metal. The priming coat preferably is applied in the latter part of the day and no painting should be done except in dry weather. The priming coat should be sufficiently thin to fill and completely wet any depressions in the metal surface. A thick paint may bridge over such depressions and leave parts of the surface less protected. Sufficient time should be allowed for perfect drying between successive coats. In fabricated structures it is better to apply only a moderately thin coat of paint before the parts are riveted together as a thick coat tends to interfere with making a tight joint and some of the paint is burned off in hot riveting. This coat should be applied before the parts leave the shop. Whether paint should be applied by spray or brush is largely an economic consideration. There seems to be little doubt that paint applied by spraying is equally as durable as that applied by hand brushing and it has a great advantage in the speed of application on large surfaces.

Accelerated drying of paints by the addition of an excessive amount of drier has been shown to shorten their useful life. It is of the utmost importance that the paint be thoroughly dry and hardened before water is admitted to the penstock. Soft paint will not stand the action of flowing water. Each coat should be allowed ample time to dry and harden, and the interior should be well ventilated during the drying period. It also is very important that the temperature of the air, plates and paint be as nearly uniform as possible to prevent condensation forming under the paint when first applied.

The American Society for Testing Materials has been conducting tests for many years on rust prevention and protective coatings and the data available from these extensive tests are probably the best there are. The following table shows clearly the respective values of the various priming paints, and is very instructive.

TABLE II—Inspection of steel plates at Atlantic City after five years' exposure.

Formula Number	Composition of Paint	Rating 1914†
34	American vermilion	7.5
5	Sublimed blue lead (basic sulphate—blue lead)	6.0
111	Burnt umber 60%, zinc lead 20%, zinc and barium chromate 20%	5.5
555	Lampblack 40%, graphite 40%, barytes 20%	5.5
21	Carbon black and barytes*	5.0
41	Chrome green	5.0
666	Red oxide of iron 50%, carbon black 5%, barytes 35%, chrome yellow 10%	5.0
888	White lead 20%, barytes 40%, chrome yellow 35%, Prussian blue 5%	5.0
20	Willow charcoal	4.5
444	Zinc oxide 60%, zinc chromate 15%, silex 20%, whiting 2%, Prussian blue 3%	4.5
10	Red lead—85% Pb_3O_4	4.0
39	Zinc chromate	4.0
49	Zinc and lead chromate	4.0
51	Magnetic black oxide	4.0
16	Natural graphite	4.0
4	Sublimed white lead	3.5
36	Medium chrome yellow	3.5
44	Prussian blue	3.5
9	American orange mineral—98% Pb_3O_4	3.0
15	Prince's metallic brown	3.0
12	Bright red oxide of iron	2.5
40	Zinc and barium chromate	2.5
100	Carbon black*	2.0
14	Venetian red	1.5
24	French yellow ocher	1.5
17	Artificial graphite	0.0
19	Lampblack and barytes	0.0
90	Lampblack	0.0
5555	Coal-tar composition	0.0

Note—All tests made on pickled plates except No. 444.
*Contained about 7 parts barytes to 1 part black by weight.
†10.0—highest rating; 0.0—lowest rating.

Paints, Etc.

Red lead undoubtedly is one of the best commercial metal protectives used. Grades running up to 98 per cent true red lead usually have less action on linseed oil than grades running 90 to 92 per cent although any hardening action that may occur is not entirely of the litharge present. Litharge is a highly basic pigment and is more rust inhibitive than a neutral oxide. It is well understood that one of the most valuable properties of red lead is its ability to set up a hard elastic film which shuts out moisture and gases that are likely to cause corrosion. This cementing action is largely due to the presence of litharge.

A point of great importance in the selection of red lead is the fineness of subdivision. Red leads that are coarse and granular may, when applied, show sagging, streaking, and running, leaving little channels of oil as points of attack for the action of the elements. The addition of a small amount of a bodied or heat-processed oil to a red-lead paint increases the flowing properties and tends to overcome the surface tension effects that cause sagging.

Another point of importance in red-lead coatings is density of film. By the introduction of a larger amount of red lead, which is quite possible due to its high specific gravity and low oil absorption, a much denser film of higher protective character is formed.

Bituminous Paints

Bituminous coatings have a wide use for special purposes. They often are made by blending refined coal-tar, asphalt, linseed oil, and oleo-resinous varnishes subsequently thinning down with turpentine or light mineral thinner. During recent years a heavy-bodied blown petroleum residual pitch has come into wide use in the manufacture of waterproofing paints. This pitch has a high melting point (300 deg. F). It is soluble in turpentine, benzol, and some mineral distillates. When in solution it may be admixed with oils for the production of rapid-drying elastic paints. The pitch has high resistance to acids and is not acted upon by the sun to the extent that coal-tar is.

When coal-tar is used in the manufacture of paints it should be refined. Ammonia and water in the tar are the active causes of non-adherence to metal. The presence of large quantities of free carbon or naphthalene in the tar will cause disintegration and checking. For refining, the crude tar may be heated to approximately 240 deg. F., holding it at that temperature until the water is evaporated. From 5 to 10 per cent of lime may be stirred in in order to neutralize the free acids. The tar then may be thinned with benzol

TABLE III—Data on most recent practice in painting penstocks.

Company Plant	Calif. Ore. Pwr. Co. Copco No. 2	P. G. and E. Co. Pit Three	San Joaquin Lt. & Pwr. Corp. Balch	Feather River Pwr. Co. Bucks Creek	Southern California Edison Co.
Is inside painted	Yes	Yes	Yes	Yes	No
Preparation of surface (Interior)	Sand-blast	Sand-blast	Wire-brushed and heated for priming coat	Banded pipe wire brushed and heated Riv. pipe sand-blasted	
Kind of Paint (Int.)					
1st coat	Inertol	Biturine or bitumastic solution	Ferrum rust-proof	Ferrum rust-proof	
2nd coat	Inertol	Enamel	Ferrum rust-proof	Ferrum rust-proof	
3rd coat	On bottom only		Abraded places only	Abraded places only	
Method of Appl.	Brush	Sol. by spray Enamel by brush			
Pipe constructed on	Piers	Ground. Piers	Piers	Piers	Piers
Preparation of ext. surface	Sand-blast	Sand-blast, Wire-brush			Wire-brush
Kind of Paint (ext)					
1st coat	Inertolbitumastic sol.	Red lead	Same as interior coating	Same as interior coating	Red lead
2nd coat	Inertol bitumastic enamel	Red lead			Red lead (light brown)
3rd coat		Red lead (black)			Red lead (gray)
Method of Application	Brush	Brush	Spray and brush		Spray and brush

or mineral spirits. If a rapid-drying paint is desired a quantity of resinous varnish may be added. The addition of China-wood oil and asbestine in a coal-tar paint made along the above lines will aid in producing a film that is not so subject to alligatoring when exposed to the sun. None of these paints, however, are as durable as linseed-oil paints when exposed to the sun.

Bituminous paints of the above composition are used as coatings upon pipe lines, in acid factories, tanks containing dilute acids, metal submerged in water, and for other similar work. For such purposes it generally is advisable first to coat the metal with a thoroughly hard-drying prime coating made by adding ¼ lb. of litharge to a gallon of prepared red lead or other rust-inhibitive paint. The bituminous paint then may be applied. Steel mine timbers subjected to sulphur water and gas, reservoir tanks containing water, submerged lock gates, tunnel metal, etc., may be efficiently preserved from corrosion by this method.

A widely used, quick-drying, jet-black asphalt varnish as specified in Circular No. 104, U. S. Bureau of Standards, requires the use of asphalt fluxed and blended with properly treated drying oil and thinned to the proper consistency with volatile solvent.

Well-refined coal-tar thinned with benzol and containing 10 per cent of dry portland cement (well mixed) is said to be very effective for protecting metals against chemical corrosion, especially chemical vapors. The U. S. Navy Department for some time has been using a mixture consisting of 4 to 8 parts coal-tar, 1 part portland cement, and 1 part, by weight, kerosene oil.

Aluminum Paint

It is well established that the ultra-violet rays of sunlight have a very marked tendency to destroy the ductility and tensile strength of the coats and produce cracking. The continuity of the film thus broken allows corrosion to commence.

Due to the great opaqueness of aluminum paint which shuts out the ultra-violet rays it is a great preserver of paint and its use in this field daily is becoming more extensive. Many large oil companies have found its value in preserving the paint on their large storage tanks, and its use on the outside of penstocks should be advantageous. It is even possible that tests might show great advantage for penstock interior work as a protection to the paint and help shut off the oxygen.

Aluminum paint should be of approved make and comply with the tentative specification of The American Society for Testing Materials.

Penstock Painting Practice

As might be expected, with the great variety and number of paints on the market, the practice in painting varies considerably. An attempt has been made to gather herein data on past experience with paints and data on present or most recent practice. Several experimental coatings, both interior and exterior, have been placed on the second pipe line at the Drum plant of the Pacific Gas and Electric Company. These were applied in the fall of 1924 and it is intended to inspect these coatings from time to time until their relative merits are established. The surface was prepared by sand blast so it is believed that the mill-scale problem does not enter. The first inspection probably will be made in the spring or summer of 1928 when it becomes convenient to have access to the pipe. Similar inspection will be made of the Wise and Pit River penstocks.

As to costs of applications, very little information is available. At Pit No. 3 the Pacific Gas and Electric Company gives a record for the interior of the penstock treated with biturine solution and enamel on a sand-blast surface: material $0.0492, labor $0.0533, total $0.1025. This is the only record of interior cost contributed.

For exterior painting only red lead applications are reported. Six cases are reported, all wire-brushed. The average cost is: material $0.0134, labor $0.0126, total $0.026.

One report is for interior and exterior combined of silica graphite: material $0.004, labor $0.03, total $0.034.

Comparative Paint Exposure (Immersion) Tests Conducted at San Francisco

Object of Test—This test is the first of a series of exposure tests on paints to reach completion. It is an accelerated or very severe test on anti-corrosive and metal priming paints to determine the relative protection afforded by them against the action of sea water and salt air.

Material Under Test—The paints selected for this exposure were those submitted by manufacturers as adapted for use on penstocks, iron poles, and as anti-corrosives on iron and steel in general. These are divided into finishing paints and primers.

Method of Test—Steel panels, 8 x 26 x 1/9 in. in size prepared by wire-brushing and washing with benzol, were painted carefully with the paints submitted. Manufacturers' directions were followed carefully and when lacking, two coats of finishing paint were applied over one coat of primer. The primers listed for independent test were not covered by a finishing coat, but the left half of each panel was given one and the right half two coats of the primer.

When finished, the panels were bolted to a frame in a position such that at low tide they were half immersed and at high tide completely covered by the bay water. This provided an exceedingly severe exposure as the bay water contains not only sea salt but, also, industrial sewage, oil, etc. The panels, being near the beach and at the low tide water line, are subjected to abrasion by floating material and by grit, etc. carried by the waves. At intervals the panels were inspected and their condition noted. When a paint had failed completely, as evidenced by serious rusting of the painted surface, the panel was removed. Thus only the best panels were left finally.

TABLE IV—Data on past experience with painting of penstocks.

Penstock	Company	Interior or Exterior	Dates painted	Preparation of surface	Kind of Paint	Number of Coats	Method of Application	Average Useful Life	Approximate Cost Per Sq. Ft. (Dollars) Material	Labor	Total	Remarks on Condition When Inspected
Drum No. 1.	P. G. & E.		1913	Wire brush	Graphite	2	Brush	Unknown				No trace, 11 years later, but pipe in excellent shape.
Drum No. 1.	P. G. & E.	Interior	1913	Wire brush	Bitumastic sol Bit. enamel	1 1	Brush Brush	Unknown Greater than 11 years	Experimental coatings			In excellent shape in 1924.
Drum No. 1.	P. G. & E.	Exterior	1913	Wire brush	Bit. enamel	1	Brush	Unknown				
Drum No. 1.	P. G. & E.	Exterior	1913	Wire brush	Graphite	2	Brush					
Wise	P. G. & E.	Interior	1916	Wire brush	Graphite		Brush	Unknown, less than 7 years				Completely gone and pipe badly pitted in 1923.
Wise	P. G. & E.	Interior repainted	1923	Sandblast.	Red lead	2	Spray and brush.	Unknown				Inspected after 1½ years, in excellent shape.
Wise	P. G. & E.	Exterior	1916	Wire brush	Graphite		Brush					
Hat Creek No. 1.	P. G. & E.	Exterior	1920	Wire brush	Graphite	1 in shop, No. 501 2 in field, No. 30	Brush			0.0151		
Hat Creek No. 1.	P. G. & E.	Interior	1920	Wire brush	Graphite	1 in shop, No. 501 2 in field, No. 827						
Hat Creek No. 2.	P. G. & E.	Interior	1920	Wire brush	Graphite					0.0145		
Drum No. 2.	P. G. & E.	Interior	1924	Sandblast.	Red lead	3	Spray and brush.	No data				Not inspected.
Drum No. 2.	P. G. & E.	Exterior	1924	Sandblast.	Red lead	3	Spray and brush.	No data				Not inspected.
Pit No. 1	P. G. & E.	Interior	1922	Wire brush	No. 501 No. 827	1 2	Spray Spray	Estimated less than 5 years				Inspected 2½ years, 15% area rusted or tuberculated, mostly along top of pipe.
Pit No. 1	P. G. & E.	Exterior	1922	Wire brush	No. 501 No. 30	1 1	Spray					In good shape in 1925.
Pit No. 3	P. G. & E.	Interior	1925	Sandblast.	Biturine solution and enamel	1 1	Brush	No data	0.0492	0.0533	0.1025	Inspected 12/16/26, after 15½ months service. Red lead: 25% surface rusted. Paint soft and pasty, easily rubbed off.
Pit No. 3	P. G. & E.	Exterior	1925	Wire brush	Red lead	3	Spray	No data	0.0217	0.0278	0.0495	Valdura—10% rusted. Cover is better than red lead. Bitumastic and biturine o. k.
Big Creek No. 3.	S. C. E. C.	Exterior	Oct., 1923	Wire brush	Red lead	3	Brush		0.01411	0.00934	0.02345	1926, good condition.
Big Creek No. 1.	S. C. E. C.	Exterior	Sept., 1924	Wire brush	Red lead	4	Spray		0.00836	0.00875	0.01711	1926, excellent. 1927, good.
Flow Line No. 2.	S. C. E. C.	Interior	Dec., 1924	Wire brush	Red lead	3	Brush					1926, not inspected. 1927, good.
Big Creek No. 1. Penstock No. 3.	S. C. E. C.	Exterior	June, 1923	Wire brush	Red lead		Brush		0.01465	0.01054	0.025119	1926, good.
Big Creek No. 1. Penstock No. 4.	S. C. E. C.	Exterior	June, 1925	Wire brush	Graphite	3			0.01192	0.00928	0.02120	1926, good, hair cracks visible. 1927, good.
Big Creek No. 2. Penstock No. 4.	S. C. E. C.	Exterior	June, 1925	Wire brush	Lead with Japan oil instead of linseed oil.	3	Brush		0.00992	0.00971	0.01963	1926, good. 1927, good. White mixed in for gray color in 1927, peeling off.
Big Creek No. 1. German pipe	S. C. E. C.	Exterior Interior	1912	Not known	Asphaltic paint (German)							Exterior, 1927, good.
Big Creek No. 2. German pipe	S. C. E. C.	Exterior Interior	1912	Not known	Asphaltic paint (German)							Exterior, 1927, good.
Big Creek No. 1. American pipe	S. C. E. C.	Exterior and interior	1913		1st graphite and red lead							Exterior good, 1927.
Big Creek No. 2. American pipe	S. C. E. C.	Exterior and Interior	1913		2nd graphite No.827							Exterior good, 1927.
Big Creek No. 2. Penstock No. 3.	S. C. E. C.	Exterior	1920		Asphaltic or coal tar.							Some rust, 1927. Good condition.
Klamath Falls	C. O. P. Co.			Air motor.	Red lead	1						
East Side	C. O. P. Co.	Both	Aug., 1924	Wire brush	Oronite	1	Brush	No data				Good, 1925.
Copco No. 1	C. O. P. Co.	Both	Dec., 1917	Wire brush	Bitumastic solution	2	Brush	6 years				Blistered and gone in Dec., 1922.
Copco No. 1-A	C. O. P. Co.	Both	Jan., 1923	Wire brush	Graphite Silica	2	Brush	No data	0.004	0.03	0.034	
Copco No. 1-A	C. O. P. Co.	Inside	Feb., 1924	Wire brush	Inertol	2	Brush	No data				Repainted upper 7 courses with 2 coats Inertol except 1st course only 1 coat for test purposes. Insp. 1/3/27. 1st course rust spots ⅛ to ¼ in. diam., spaced 2 or 3 in. 6 courses some rust but not as bad as first course.
Copco No. 2	C. O. P. Co.	Interior and top half of exterior	July, 1925	Sandblast.	Inertol	2	Brush	No data				
Copco No. 2	C. O. P. Co.	Bottom half of exterior	July, 1925	Sandblast.	Bitumastic solution and enamel	1 each	Brush Swab	No data				
Cazadero	P. E. P. Co.	Interior	1905	Unknown.	Ferrubron	Not known	Not known	Perfect in 1915				Other penstocks painted in 1909-1910 with some other product in bad shape at same inspection.

Results of Test

Anti-Corrosive Paints—The paints broke down in very rapid order commencing almost immediately after exposure. The first signs of failure usually showed at the edges. This, however, was not considered a reliable indication of failure and initial breakdown was not recorded until the middle of the painted surface had blistered, cracked or checked. This, as a rule, happened suddenly and without apparent bearing upon the condition of the edges. Initial failure by checking or "alligatoring" was conceded to have occurred only when the cracks had penetrated almost through the paint.

Blistering was followed by breaking of the blisters and the formation of rust pits. Cracking allowed penetration of water which caused the iron to rust under the paint, followed by peeling. Checking usually was associated with a good bond so that rust was confined to the check lines. A few paints scaled or flaked. These either were brittle or were distintegrated by the water and abrasion. Roughened surfaces became covered with barnacles and seaweed which probably contributed to removal of the paint. Final failure was recorded when the panel started to rust badly due to rapid breaking up of the paint.

Of the 41 finishing paints tested:

Sample No. 37 lasted 215 days showing few pits and no checking.
Sample No. 222 at this period was chipping off badly and the metal rusting slightly.
Sample No. 226, chipping badly and metal rusting badly.
Sample No. 455, "Alligatered" with rusting in checks.
These four were the only samples remaining after 7 months' test.
1 sample broke down right away and disappeared in 5 days.
5 samples had an initial break-down in 5 days and broke down finally in about 2 months.
19 samples had an initial break-down in about 2 months and final break-down in about 2½ months.
13 samples had an initial break-down in about 2 months and final break down in less than 4 months.

Primers—The failure of these paints was exceedingly rapid. Bad discoloration due to rusting of the metal under the paint was taken as initial break-down. On the single coat this usually was the only warning, as the rust broke through and distintegrated the paint rapidly thereafter. The two-coat surface usually blistered coincident with the discoloration and later cracked.

26 samples tested.
9 1-coat samples had initial break-down in 5 days.
8 in 6 days.
4 in 11 days.
2 in about a month.
3 in about 2 months, final break-down in about 2½ months.
7 2-coat samples had initial break-down in 5 days.
5 2-coat samples had initial break-down in 6 days.
3 2-coat samples had initial break-down in 11 days.
11 2-coat samples had initial break-down in about 60 days
Two samples lasted more than 100 days, one lasting 121 and the other 112 days.
The others were gone in less than 3 months, 6 in 1 month, 8 in 2 months.

In judging these primers the duty for which a primer is designed must not be lost sight of. Its chief purpose is to take a tenacious hold of the slick metal surface and to provide a "toothed" or slightly rough surface upon which the finishing coat may be applied, i. e., the priming cost is a bonding coat. A paint of this nature is likely to be porous, and few, even of metal primers are intended to seal against moisture. If a primer which also seals is desired, then the leaders of

TABLE V—Data on past experience with painting of penstocks.

Location	Interior or Exterior	Date Painted	Preparation of surface	No. of Coats	Kind of Paint	Method of Application	Average Useful Life	Remarks on condition when inspected
Klamath Falls..	.....	.....	Air motor..	....1.....	Red lead.....	.....	.....	.....
Drum No. 2....	Interior.....	1924.....	Sandblast..	....3.....	Red lead.....	Spray and brush.	No data.....	Not inspected.
Drum No. 2....	Exterior.....	1924.....	Sandblast.	....3.....	Red lead.....	Spray and brush.	No data.....	Not inspected.
Wise.....	Interior re-painted...	1923.....	Sandblast..	....2.....	Red lead.....	Spray and brush.	Unknown....	Inspected after 1½ yrs., in excellent condition.
Pit No. 3.....	Exterior.....	1925.....	Wire brush	....3.....	Red lead.....	Spray and brush.	No data	Insp. 12/15/26 after 15½ mo. service. Red lead, 25% surface rusted. Paint soft and pasty, easily rubbed off.
Big Creek No. 2. Penstock No. 4..	Exterior.....	June, 1925	Wire brush	....3.....	Red lead.....	Spray and brush.	No data.....	1927, Good. White lead mixed in for gray color in 1927 peeling off.
Big Creek No. 3.	Exterior.....	Oct., 1923	Wire brush	....3.....	Red lead.....	Brush.....	.....	1926, in good condition.
Big Creek No. 1.	Exterior.....	Sept.,1924	Wire brush	....4.....	Red lead.....	Spray.....	No data.....	1926, excellent, 1927, good.
Flow Line No. 2.	Interior.....	Dec., 1924	Wire brush	....3.....	Red lead.....	Brush.....	.....	1926, not inspected.
Big Creek No. 1. Penstock No. 3..	Exterior.....	June, 1923	Wire brush	.....	Red lead.....	Brush.....	.....	1927, good. 1926, good.
Drum No. 1....	Interior.....	1913.....	Wire brush	....1.....	Bitumastic sol.	Brush.....	Unknown....	Excellent, 1924.
				....1.....	Bit. enamel....		Greater than. 11 yrs.....	.....
Drum No. 1....	Exterior.....	1913.....	Wire brush	....1.....	Bitumastic sol.	.....	Unknown.....	.....
				....1.....	Bit. enamel....			
Pit No. 3.....	Interior.....	1925.....	Sandblast..	....1.....	Biturine sol. and	Spray.....	No data.....	Valdura, 10% rusted. Cover is better than red lead.
				....1.....	enamel.....			Bitumastic and Biturine O. K. 15 mo. service.
Copco No. 1....	Interior and Exterior.	Dec., 1917	Sandblast..	....2.....	Bitumastic sol..	Spray.....	6 yrs.....	Blistered and gone in Dec., 1922.
Copco No. 2....	Bottom half. exterior.	July, 1925	Sandblast..	....1.....	Bitumastic sol.	Brush swab.....	No data.....	.....
				....1.....	Bit. enamel....			
Drum No. 1....	Exterior.....	1913.....	Wire brush	....2.....	Graphite No. 1.	Brush.....	.....	.....
Wise.....	Interior.....	1916.....	Wire brush	.....	Graphite No. 1	Brush.....	Unknown,less than 7 yrs..	Completely gone and pipe badly pitted in 1923.
Wise.....	Exterior.....	1916.....	Wire brush	.....	Graphite No. 1	Brush.....	.....	.....
Hat Creek No. 1.	Exterior.....	1920.....	Wire brush	.....	Graphite No. 1	Brush.....	.....	.....
Hat Creek No. 1.	Interior.....	1920.....	Wire brush	.....	Graphite No. 1	.....	.....	.....
Hat Creek No. 2.	Interior.....	1920.....	Wire brush	.....	Graphite No. 1	.....	.....	.....
Drum No. 1....	.....	1913.....	Wire brush	....2.....	Graphite No. 1	Brush.....	Unknown....	No trace 11 yrs. later, but pipe in excellent condition.
Copco No. 1-A..	Interior and exterior.	Jan., 1923	Wire brush	....2.....	Graphite No. 1	Brush.....	No data.....	.....
Pit No. 1.....	Interior.....	1922.....	Wire brush	No. 501—1 No. 827—2	Graphite No. 2	Spray.....	Estimated less than 5 years.....	Inspected 2½ yrs. 15% of area rusted or tuberculated, mostly along top of pipe.
Pit No. 1.....	Exterior.....	1922.....	Wire brush	No. 501—7 No. 30—1	Graphite No. 2	Spray.....	.....	In good condition in 1923.
Big Creek No. 1. Penstock No. 4..	Exterior.....	June, 1925	Wire brush	....3.....	Graphite No. 2	.....	.....	Good, 1926, hair cracks visible. 1927, good.
Eastside.....	Both.....	Aug., 1924	Wire brush	....1.....	Oronite.....	Brush.....	No data.....	Good in 1925.
Copco No. 1-A..	Interior.....	Feb., 1924	Sandblast..	....2.....	Inertol.....	Brush.....	No data.....	Repainted upper 7 courses with 2 coats except 1st course—only 1 coat for test purposes.
Copco No. 2....	Interior and top half of exterior.....	July, 1925	Sandblast..	....2.....	Inertol.....	Brush.....	No data.....	Insp. Jan. 3, 1927. First course rust spots ⅛ to ¼ in. diam. spaced 2 or 3 in. 6 courses some rust, but not as bad as 1st course.

this test should be effective. If bond alone is desired and the finishing coat is depended upon to seal, then some of those lower in the list might be more effective.

Since the foregoing report was made, another report has been gotten out on exposure tests made of the same paints at Davis, California. Paints which stood up best at San Francisco failed first at Davis and vice versa. This complicates the situation and shows that conclusions cannot be made on any test at any one particular location.

Conclusion

It is safe to draw the following conclusions regarding penstock painting, which is not very different from the painting of any steel work except that the interior seldom accessible for re-painting in a satisfactory manner.

Commencing with the manufacture of the pipe, it is very important that the shop coat, if any, be applied to a well sand-blasted surface, that the temperature conditions be satisfactory and the paint be of a properly designed mixture. It would be very desirable to have plates oil-dipped while hot as this has been found to be one of the best methods of protecting steel prior to fabrication.

Subsequent coats should be applied to a well cleaned surface and given ample time between coats for drying and hardening. At least two weeks between coats is recommended by authorities for the interior of a pipe.

The exterior of the pipe should be protected from the ultra-violet rays by an intensely opaque coating. First-class aluminum paint fulfills this duty better than any other known medium, providing a fine metallic coating over the paint very similar to a galvanized surface.

It is hoped that the hydro companies will see that it is to their advantage to make more frequent inspections of the interior of penstocks, as there is evidence that much lost head is due to corrosion. In other cases, where considerable silt is carried in the water, considerable corrosion may be going on without visual evidence of it in the pipe.

Discussion of Red Lead

The following correspondence is pertinent to this question of painting:

NATIONAL LEAD COMPANY
Research Laboratories
105 York Street

Brooklyn, N. Y.
March 15, 1928.

Mr. A. W. Scott,
National Lead Company,
235 Montgomery Street,
San Francisco, Calif.

Dear Mr. Scott:

When I was in San Francisco I called on the engineer of the Great Western Power Company and discussed with him the painting of penstocks. He gave me a memorandum he had prepared and asked me to comment on the section describing the use of red lead, p. 4 of the memorandum.

I am giving you a discussion of this subject on a separate sheet.

The painting of the outside of a penstock is not a particularly difficult problem as it is essentially the painting of steel under exterior atmospheric exposure. Out regular formulas and recommendations for painting steel should be used and the equipment can be maintained in good condition because repainting is possible whenever required.

The painting of the interior of a penstock is an entirely different problem and requires careful consideration. After the water has been admitted to the penstock, the paint on the interior cannot continue to dry and furthermore, contact with water has a considerable softening effect on paint. For this reason, paint used on the interior of a penstock should be as dry, hard, and well matured as possible, before the water is admitted. The metal should be clean and free from loose paint and scale and the painting should be done when the metal is dry and when the weather is warm enough to permit the paint to dry with fair rapidity.

A heavy coating of tar applied in the molten condition could be used with considerable satisfaction, but such treatment is expensive and difficult and cannot be classed with protective coatings of paint which are applied by brush at ordinary temperatures.

Asphaltum and tar paints made by dissolving the asphaltum or tar in a volatile solvent cannot be compared to heavy molten tar coatings and such solution paints will not give any degree of satisfaction on the interiors of penstocks.

If a paint is to be used which can be applied with a brush at ordinary temperatures, no better practice can be followed than the application of three coats of red lead paint. The coats should all be mixed on the same formula and should consist of our No. 1 Liquid Red Lead, Paste Red Lead thinned with two gallons of linseed oil or dry red lead mixed at the rate of 33 lb. of pigment to 1 gallon of linseed oil. All of these formulas produce paint of approximately the same composition. It is well to use ⅓ boiled lineed oil and ⅔ raw linseed oil or half boiled linseed oil and half raw linseed for thinning the red lead paste or for mixing with the dry red lead. Either formula would be satisfactory.

Just before the paint is applied, finely powdered litharge should be added at the rate of 2 lb. to each gallon of paint. Only the amount of paint which will be used within a short time should have the litharge added to it because after the litharge is added, the paint may thicken if it is kept for more than a day.

For the best results, each coat should be well brushed out and an excessive length of time should be permitted between coats for the paint to dry and after the finishing coat has been applied. If possible, two weeks should be allowed between coats and after the application of the finishing coat but of course this length of time is sometimes impractical.

In repainting an old penstock, the conditions are frequently very unsatisfactory because the interior of the metal continues to be wet for some time after it is emptied. It is possible that a current of air could be blown through the penstock from the lower end after the water has been drained so as to dry the interior before the paint is applied. Work done in this way will give the best possible results which can be secured with any paint except perhaps the heavy molten tar coatings to which we have previously referred.

This is the best advice we can give and we hope it will be of interest to the Great Western Power Company.

Very truly yours,

By R. L. Hallett.

A Discussion of the Section On Red Lead Given on Page 4 of the Memorandum Referred to in Foregoing Letter

The statements made in the original memorandum are fairly accurate and comprehensive but some additional comments might be of interest.

Red lead paint is the most durable and satisfactory protective coating for iron and steel surfaces. Red lead for painting purposes is made in different grades varying from 85 per cent true red lead to 98 per cent or 99 per cent of true red lead. Perhaps red lead pigment is to a certain extent an inhibitor of corrosion, but the value of red lead paint lies in the fact that after it has been applied to an iron or steel surface it permanently remains as an unbroken, relatively elastic film, adhering closely to the metal. The protective qualities of any paint depend upon the paint film remaining as an unbroken coating which keeps the air and moisture away from the metal surface. Red lead paint possesses these characteristics to a remarkable degree and it has become standard practice to use red lead paint for the protection of iron and steel surfaces of all kinds.

Red lead pigment varies somewhat in fineness and uniformity of particles and coarse pigments sometimes will cause streaking and sagging soon after the paint is applied. A course pigment also results in an uneven film, thicker in some places than in others, which means that the thinnest portions do not have sufficient thickness to give satisfactory durability. The highly oxidized red lead containing more than 97 per cent of true red lead is very fine and uniform in particle size. Paint made with this highly oxidized red lead gives a resulting film of uniform thickness and such paint is more durable than if the less uniform pigment of lower oxidation is used.

Generally speaking, a paint film with a fairly high pigment concentration is more durable than one with low pigment concentration, and for this reason a red lead paint film should not be too greatly thinned with oil.

Perhaps the most suitable formula for general use is 33 lb. of dry red lead to 1 gal. of linseed oil which corresponds to 100 lb. of paste red lead to 2 gal. of linseed oil. For the priming coat on iron and steel the pure red lead paint without tinting materials should be used but in the subsequent coats small amounts of tinting materials to produce various shades may be added if desired.

Pacific Coast Developments in Automatic Hydro-Electric Plants*

This general report of the subcommittee's work for the year 1927-28 contains a summary of the ideas presented in the papers of the various members of the committee.

The use of automatic features in hydro-electric plants is not a new idea. Many of the features of the standard equipment of plants are automatic in that they take care of situations that may arise without the action of the operators in charge. The most highly developed automatic feature is the oil pressure governor and servomotor. Voltage regulators also are a part of the automatic apparatus. These features have been available for many years and it was only necessary to carry the idea of protective and automatic devices one step further to permit doing away with the operators except for occasional visits of inspection and maintenance.

The first step was to use the equipment as formerly designed, adding only devices to shut down the unit when need arose and by ringing alarm bell to call the attendant who would then correct the abnormal condition and in due course place the plant in service again. This so-called semi-automatic type is the most common on the Pacific Coast. The San Joaquin Light & Power Corporation in 1919 placed in operation two induction generator plants so designed that one operator at each location was suffcient for the 24-hour service. The Southern California Edison Company in 1920 made additions to its old installation at Mill Creek No. 1 so that no operator would be necessary at the plant, starting up being accomplished by operators from a nearby station. This installation was so successful that in 1922 this company placed eight more small plants on a semi-automatic basis. The Ontario Power Company in 1922 placed a small unit in service with full automatic operation. This was a new installation and the protective and automatic equipment was furnished

* Report of subcommittee of hydraulic power committee—C. C. Long, chairman. P. B. Garrett, E. F. Maryatt, W. E. Melarkey, R. S. Quick, C. P. Rhine.

by the electrical manufacturer. The starting and stopping were accomplished by a push-button control at a distant substation. The San Joaquin Light & Power Corporation later changed two more of its power stations to semi-automatic operation using synchronous generators and has just finished reconstruction of the Tule power house where two units of 5,000 hp. each are so controlled. The Pacific Gas and Electric Company placed its Coal Canyon plant on semi-automatic operation in 1926. Its Deer Creek plant was completed the latter part of 1927 and at the present time it is building the Spaulding No. 3 plant which is to be full-automatic and have a capacity of 8,000 hp. in one unit.

This brief summary of the experience of the California companies with automatic operation indicates that the early experience was satisfactory and leads to an extension of the idea to other plants in each case. The Southern California Edison Company has under design the project of converting two of its older statioins that have been under semi-automatic control since 1922 to full-automatic with new waterwheels and generators installed.

An analysis of the subject which is more fully given in the papers by members of the subcommittee boils down to the following conclusions:

It is advisable and economical to establish semi-automatic or automatic operation in any plant where the continuous operation of the plant is not vital to maintain system service. The conditions that govern are that the automatic plants must not be a large percentage of the total generating power of the system. Also, the plants so controlled must not be vitally necessary in system operation for testing lines. When these conditions obtain, the experience has shown that semi-automatic operation will usually be the most economical. The equipment in a hydro-electric plant and the structures and grounds surrounding it are such that one man can be kept busy on routine maintenance work especially at the older plants. If the routine maintenance work is such that one man's time is occupied thereby, very little is gained by the additional capital cost for complete automatic operation. However, where plants are designed and simplified with the idea in mind of minimum equipment and maintenance work, it may be possible for one man to maintain two or more plants in the same vicinity. Also, as in the case of the Spaulding No. 3 plant of the Pacific Gas and Electric Company where the installation can be operated for only a portion of the year due to water conditions, it is undesirable to locate maintenance men at the plant site. These conditions will justify the expenditure necessary to make the plants full-automatic, requiring only the operator's attention when there is failure of equipment causing a lockout and for routine inspection.

It is remarkable that the experience of the various companies has been so uniformly successful with the crude equipment that was used for the early installations. Recently, the manufacturers have been designing equipment especially for these automatic installations and we can expect even a higher degree of precision from this specially designed apparatus.

The first difficulty that was met was the problem of regulating the load to the amount of water available. The operating companies designed various float control mechanisms and have met the condition for semi-automatic operation where an operator was available to take care of abnormal conditions. The usual solution was a combination of time clock and relay with the float switch such that the waterwheel load was increased during a definite period, usually a few seconds every few minutes, while the float in the forebay was in the high position, and the reverse when the float was in the low position. To take care of emergencies when the increase or decrease in flow was abnormal and too fast for the timing best suited for a normal operation, an alarm at extreme upper and lower positions of the float called the operator to take care of the situation. The manufacturers have now developed devices whose principle is to have a definite load on the waterwheel for each elevation of water in the forebay. This may be accomplished by a Seslyn transmitting equipment, tying the float level to the load control device. Another scheme uses two rheostats arranged in much the same way as a Wheatstone bridge whereby the load control motor in opening and closing the waterwheel gates moves a rheostat arm in exact synchronism with a rheostat arm connected to the float mechanism. These devices have been applied and are working very satisfactorily in actual service.

The natural thing to do when converting an existing plant to automatic operation was to use as much of the equipment installed as possible. For this reason the mechanism for operating the waterwheel gates, or the needle nozzles as the case might be, was controlled and operated by oil pressure governors and servomotors. The waterwheel manufacturers have now developed simplified machanisms for this work which are particularly adapted for full automatic plants. The idea of this apparatus is to start and stop the unit by hydraulic pressure from the penstock and vary the load with an electric motor. This combination seems to give all of the safety features necessary together with a simplified equipment. Considerably more can be done by the manufacturers to increase the safety of units and simplify valve controls and operating mechanisms.

The problem of synchronizing has become rather simple. Where the uit is a small percentage of the total generating capacity of the system, it is usually permissible to close in the generator switch with no field at approximately synchronous speed. When the field is applied the generator will automatically be pulled into step. At other locations where such a procedure would create too much disturbance in the system, automatic synchronizing equipment can be installed that will match the speed of the incoming unit to the line and close the generator switch under proper phase conditions.

Supervisory equipment has been developed for substation practice which is also applicable for hydro-electric installations. These control features, however, are always made supplementary to the automatic features to take care of abnormal conditions and introduce the personal element into the operation when desired by the system operators.

The experiences of the operating companies have been so universally successful that the field of application of automatic equipment will no doubt be extended to larger and more important plants in the near future. In addition to the economical savings due to smaller investment for operators' cottages and camp equipment and the decreased number of attendants necessary, there is a considerable advantage in having automatic equipment to take care of abnormal conditions that is independent of the personal element. Properly designed, automatic equipment will not make mistakes and its never sleeps.

It is in keeping with the modern trend to do nothing by man power that can be done by equipment. This gives greater latitude for the development of each individual, increasing his usefulness. The application of automatic equipment to hydro-electric plants is therefore a logical development from both the economical and the social standpoints. We are only at the beginning.

Automatic and Semi-Automatic Hydro Plants of the Pacific Gas and Electric Company

By E. F. Maryatt*

Spaulding No. 3 power house of the Pacific Gas and Electric Company is the direct result of a co-operative agreement between the Pacific Gas and Electric Company and the Nevada Irrigation District.

The Nevada Irrigation District comprises 209,610 acres of land in Nevada County, Calif., all considerably downstream from the Deer Creek, Drum, Spaulding group of power houses belonging to the Pacific Gas and Electric Company. The Nevada Irrigation District secured water storage facilities so situated that the water can be passed through these plants and afterward used for irrigation purposes.

Hydraulic Features

The major storage reservoirs of the irrigation district are the Jackson reservoir, the Milton reservoir and the Bowman reservoir. The Jackson and Milton reservoirs are on the Middle Fork of the Yuba River and so located that the water from the Jackson reservoir passes through the Milton reservoir. From the Milton reservoir water passes through the Milton-Bowman tunnel, 21,200 ft. in length, into the Bowman reservoir which is located on a tributary of the South Fork of Yuba River and is about ten miles from Lake Spaulding of the Pacific Gas and Electric system.

From Bowman reservoir water passes through 2.5 miles of Lennon type metal flume along the cliffs, six

* Report of subcommittee of hydraulic power committee.

miles of open ditch in earth and solid rock, 1.17 miles of tunnel and 0.33 mile of siphon arriving finally near the top of a ridge approximately 320 ft. in elevation above Lake Spaulding. At the foot of this ridge on the shore of Lake Spaulding is the site of Spaulding No. 3 power house.

Lake Spaulding has a capacity of 74,488 acre-ft. and is the property of the Pacific Gas and Electric Company. Most of its water comes from Fordyce Creek and the South Fork of the Yuba River, but there also are other Pacific Gas and Electric storage reservoirs above which feed into it. The Nevada Irrigation District water is not stored in Lake Spaulding, but passes through the lake for distribution below.

Below Spaulding dam, which is about 1½ miles from Spaulding No. 3 power house, are Spaulding No. 1 and Spaulding No. 2 each using water independently from Lake Spaulding. Spaulding No. 1, with an effective head of 190 ft. passes water down for re-use at Drum power house at an effective head of 1,285 ft. The portion received from the Nevada Irrigation District is returned to the district for irrigation purposes and the remainder flows on down to Halsey and Wise power houses.

Spaulding No. 2 power house, with an effective head of 335 ft., passes water on through to Deer Creek power house at an effective head of 790 ft., after which the portion of water controlled by the irrigation district is returned to it for irrigation purposes.

Spaulding No. 3 therefore, by virtue of its relation to the rest of the system and because of the fact that the water used by it is irrigation water, has several peculiar features:

1. It is a seasonal plant. Its period of operation will be approximately nine months, namely, July 1 to and including the following March.
2. It is a uniformly steady-load plant. There is no forebay capacity and the contract with the irrigation district requires that the water be accepted at Spaulding No. 3 at a uniform rate of flow.
3. Its load is controlled by stream flow, since there is no forebay. To avoid wasting water the plant is fitted with an automatic water-level-controlled load adjustment.
4. Tail-race spillway. Lake Spaulding, being a storage reservoir, has a water-level variation which may be as much as 175 ft. Therefore it is evident that the lake water elevation cannot be depended upon to form a draft-tube seal. A concrete spillway was built which at times is submerged, but which has a spill crest elevation sufficiently high to hold enough water to seal the draft tube even when the lake surface elevation may be much lower.

Since the elevation of this spillway must be adjusted to form a seal at no load, it follows that when the plant operates at full load an additional tail-water depth will result which will reduce the effective head on the plant. To reduce this loss to a minimum an automatic float-operated radial gate is installed in an opening in the concrete spillway. This gate will operate automatically to pass any excess water over and above the amount required to maintain a draft-tube seal. The turbine was located as near the maximum lake surface elevation as possible further to reduce the head loss between the tail-race and the lake.

Plant Equipment

Spaulding No. 3 power house contains a single 8,000-hp. horizontal-shaft reaction turbine operating under an effective head of 306 ft. and driving a 7,000-kva., 6.6-kv., 450-r.p.m. generator.

Power is stepped from 6.6 kv. up to 60 kv. through a bank of three 2,500-kva. transformers and delivered to the 60-kv. bus at Spaulding No. 1 power house for transmission over the 60-kv. lines radiating from that station.

Hydraulic Turbine Controller and Shut-down Device—A station operating as Spaulding No. 3 operates, under continuous block-load and at the same time feeding into a relatively large system, the speed of which is controlled by one or two other stations, if supplied with a governor and all the necessary auxiliary governor oil systems, seldom makes use of that governing equipment as such. The only use is that of shutting down the turbine and of protecting against overspeed. A modern governor itself requires very little attention, but it must be accompanied by oil pumps, an air compressor, oil storage tanks, etc., which greatly complicate the automatic control of a station. The failure of any of this secondary equipment might mean disaster to the station. Therefore much simpler and more positive equipment was developed to perform these functions, thereby eliminating a large quantity of governing and oil-handling equipment with its attendant expense, complication and hazard, to a full automatic station.

The special equipment developed for this plant is known as an "automatic hydraulic turbine controller and shut-down device." (See Fig. 1.) The controller operates by water pressure taken directly from the penstock because penstock pressure always is available when any operation is required. When there is no penstock pressure it is not necessary to operate a shut-down device. This source of operating pressure when equipped with suitable straining equipment not only is direct, positive and ever-present when needed, but is absolutely reliable. Its use is ideal in connection with automatic power houses.

The controller consists of a cylinder containing a differential piston and a motor-operated jack screw. One side (X) of the piston has approximately twice the area of the other side (Y). The small area side (Y) of the piston is subjected continuously to penstock pres-

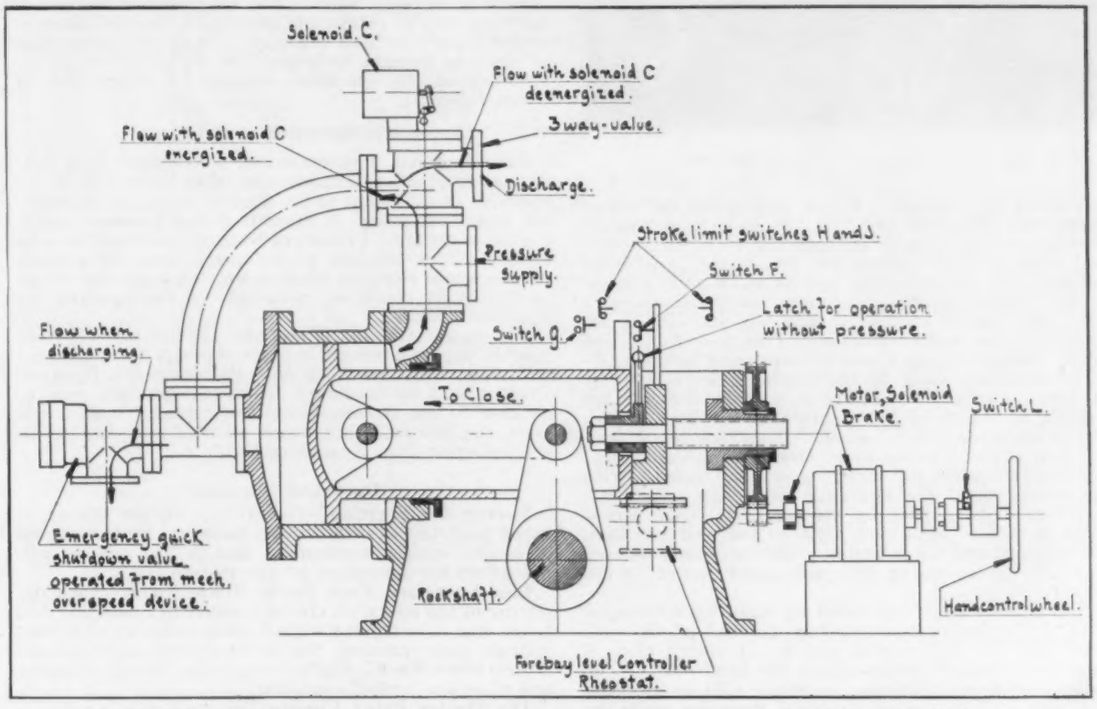


Fig. 1. Automatic hydraulic controller for Pacific Gas and Electric Company's Spaulding No. 3 plant.

sure, which, acting upon the piston, will close the turbine gates. Pressure to the large area side of the piston is controlled through a solenoid-operated valve (C) one position of which admits penstock pressure to the cylinder and the other position of which opens the cylinder to the drain. When pressure to the large side of the piston is admitted by this valve the piston is moved to the opposite end of the cylinder, at the same time resisting the pressure from the penstock that is acting on the small side of the piston and also exerting sufficient energy to open the turbine gates.

It may be noted here that this device, once it starts to open or close the gates, will continue until the end of the stroke is reached. There are other functions required of a device of this kind in an automatic station. The turbine gates must be opened a slight amount, just sufficient to start and bring the turbine up to speed, and must be held in that position until after the unit is synchronized and is ready to pick up load. The device also must adjust the gates for a definite load requirement and hold them there, or make a new adjustment as may be required. To meet these requirements there was included a motor-operated jack screw which was placed at the opposite end of the piston from that to which the gate mechanism is attached. The jack screw is not mechanically connected to the piston, but controls its position by pushing it in ordinary jack-screw fashion or backing away to let the water move it in the other direction. This provides an additional means of shut-

Fig. No. 2. Automatic hydraulic controller.

ting down the turbine. If the jack screw is backed away from the piston and if at the same time water is admitted to the cylinder through the electrically operated valve (C) the piston will follow the jack screw and open the turbine gates just as much as is allowed by the position of the jack screw. A motor-operated jack screw can be controlled definitely and can be adjusted for any desired position. This then fulfills one of the additional requirements mentioned before.

The starting setting for the turbine gates is fixed by the lower limit position of the jack screw which is adjustable by means of the location of the limit switch (H) in the motor control circuit. This jack screw position is a slight distance away from the hydraulic controller piston when the turbine gates are closed. With this arrangement the hydraulic controller piston will open until it is stopped by the end of the jack screw. There it is held until such time as the unit has been synchronized and the set-up is made for taking on load by means of operating the jack screw motor in the proper direction.

The device may be operated by hand by rotating a latch (L) which couples securely the end of the jack screw with the differential piston. A clutch then is operated to connect mechanically the handwheel to the motor driving mechanism. A switch (M) is provided as an interlock to prevent electrical operation while the handwheel is engaged. Fig. 2 shows the completed mechanism.

Butterfly Valve Control—The butterfly valve and its accompanying by-pass valve make use of the differential-piston idea for their operation. (See Fig. 3.) The smaller area of the by-pass valve piston is subjected to penstock pressure, tending to open the valve. It will open when pressure is released from the opposite and larger area side of the piston. The cylinder for closing the butterfly and the by-pass are interconnected, being closed and held closed by the same water. The opening operation of the butterfly is accomplished by the operation of control valve (B) which admits water into the butterfly-valve operating clyinder.

The butterfly valve is so interlocked that it cannot open until the casing has been filled by the by-pass valve. (See "Automatic Operation of Plant.")

Float Control—The water-level load control equipment consists essentially of two face-plate type rheostats and a balanced relay. One rheostat is at the forebay with its variable arm connected to a float in such a manner that the arm will follow the float to any level it may take. The other rheostat is on the automatic hydraulic controller. The rheostat arm is connected to the controller such that there always will be a definite relation between positions of the controller jack-screw and the rheostat arm. The balanced relay acts upon the motor driving the jack screw and will drive the same until a balance is obtained between the two rheostat resistances.

Emergency Overspeed Shut-Down—The plant is provided with an overspeed device to which is attached an electrical contact which, when the circuit is completed, will shut the unit down by means of its automatic electrical equipment. So much depends upon the absolute reliability of a device for shutting down the station in case of overspeed that a request was made for an entirely independent auxiliary mechanical overspeed device.

To meet this requirement there was developed a flyball overspeed trip attached directly to the turbine shaft, a pilot valve and hydraulically controlled drain valve. At a setting slightly above that of the electrical overspeed device this flyball will trip the pilot valve which releases pressure from the drain valve (D), Fig. 1, allowing it to open and drain the larger area end of the "hydraulic controller" cylinder, closing the turbine gates. This in turn trips the oil circuit-breaker and shuts down the station.

This device is entirely separate and independent of any of the other equipment.

This covers the automatic equipment developed especially for this plant. The other automatic equipment consists of relays and contactors, the operation of which is more or less common. No special description of them is thought necessary for the complete understanding of the operation sequence, a description of which follows:

Automatic Operation of the Plant

Spaulding No. 3 power house is designed as a full-automatic plant. It is intended that there will be no operator or attendant at the station normally, the nearest attendant being at Spaulding No. 1 power house, 1½ miles distant. Protective features therefore were so designed that troubles of an intermittent or passing nature would shut the plant down, but leave the set-up such that it could be restarted by the operator at Spaulding No. 1.

The equipment which protects against more serious trouble or those which indicate damage to equipment will shut down and "lock out" the automatic features. Then it will be necessary for a maintenance man to go over to the station, locate the damage, if any, and reset the lockout relay which enables the plant to be started again from Spaulding No. 1.

Operation Sequence

Energy for Starting—The control circuit energy is taken from the 48-volt storage battery. By this means of control supply momentary dips in line voltage will not affect the operation of the station.

Line Energized From Power House No. 1—Upon the closing of the 60-kv. oil circuit breaker at Spaulding No. 1, the line is energized with a three-phase symmetrical voltage thus causing the reverse-phase and phase-failure relay No. 47, Fig. 3, to open its "break" contacts and close its "make" contacts.

The Master Relay Closes—The master relay No. 3

will close when the contact of 47 in series with master relay No. 3 is closed, provided the lockout relay No. 30 has not been operated, the underspeed contact No. 14 is closed, the line has previously been de-energized, thus allowing master element No. 1 to drop out and close its "break" contact in the circuit of No. 3, and provided further that none of the protective devices short-circuiting the operating coil of No. 3 are closed. In picking up, master relay No. 3 locks itself in through one of its own "make" contacts and at the same time closes a contact to energize bus BP3.

The Wheel and Generator Accelerate—The first action resulting from the energizing of bus BP3 is the picking up of the controller relay No. 65. This relay performs two functions. It causes master element No. 1 to pick up and lock itself in. It also causes valve "A" of the automatic hydraulic controller to be energized rotating the same 90 deg. in a clockwise direction, thus draining the small end of the butterfly operating cylinder and at the same time releasing pressure from the by-pass. This allows the penstock pressure applied to the nose of the by-pass piston to open the same and admit water to the turbine casing.

Filling of the turbine case with water under pressure causes contact "K"" to be closed and valve "B" to be energized. This causes penstock pressure to be applied to the top of the butterfly operating cylinder and the butterfly slowly opens. When the butterfly valve reaches the full open position limit switch "D" is closed and valve "C" thus is energized, providing also that the jack-screw mechanism is in the full shutdown position and limit switch "F" is closed. The operation of valve "C" admits penstock pressure to the large end of the differential piston hydraulic controller causing the piston to move to the position required for starting and accelerating of the unit. The unit thus is caused to accelerate until the synchronous speed contacts of the speed relay No. 13 indicate that the generator has reached a speed of approximately 95 per cent of synchronism.

The Generator is Connected to the Line—The operation of contact 13 of the speed relay closes oil circuit breaker relay 52X whose main contacts complete the solenoid circuit 52 of the oil circuit breaker thus causing it to close. By referring to this circuit it may be seen that a "make" interlock of 52 completes the circuit to oil circuit breaker anti-pumping relay 52Y, which picks up and forms its own holding circuit. In addition to this a contact of 52Y parallels the operating coil of 52X thus short-circuiting it and causing relay 52X to open and de-energize the solenoid 52. Since relay 52Y has formed its own holding circuit and put a permanent

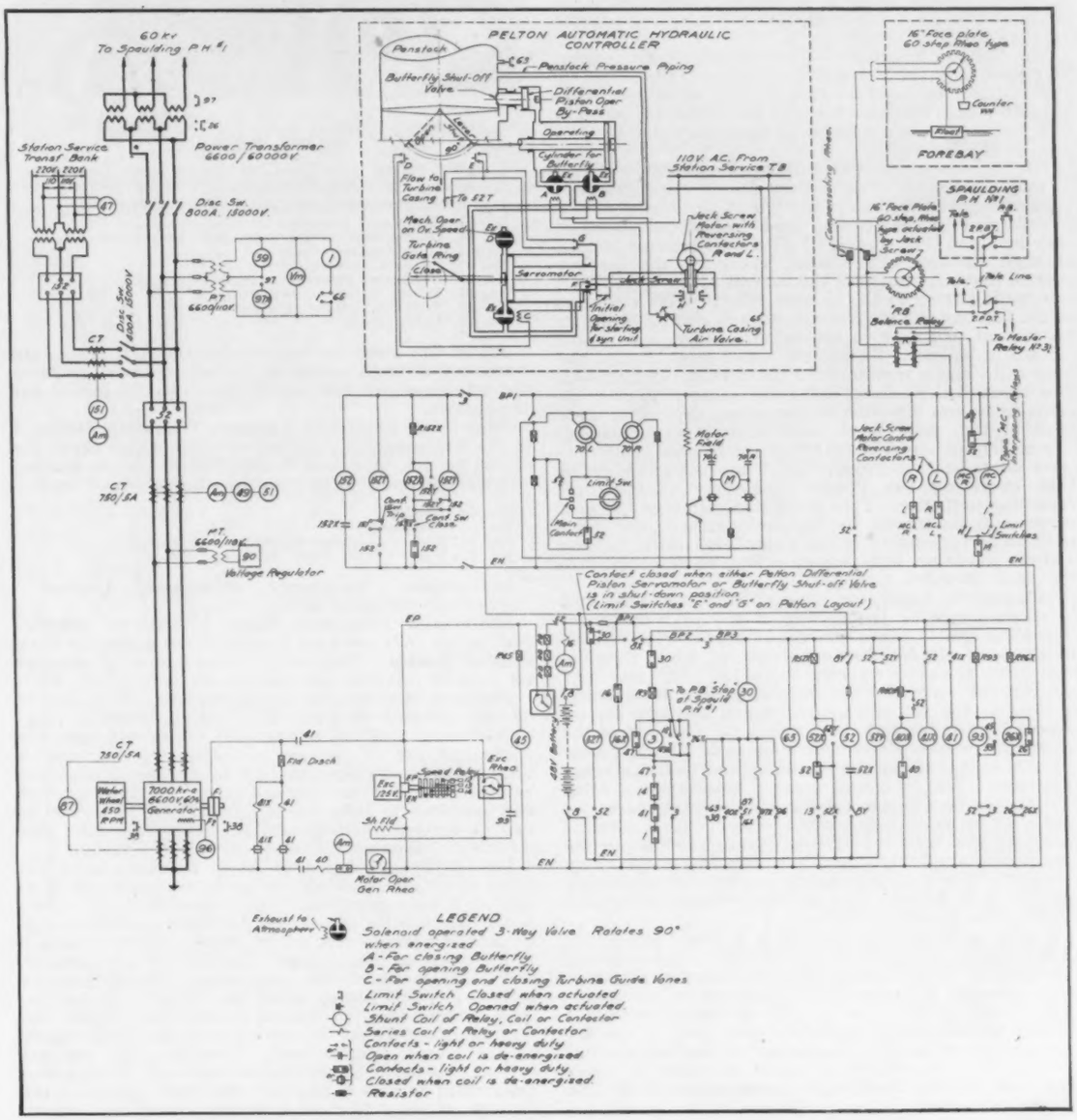

PELTON AUTOMATIC HYDRAULIC CONTROLLER
Penstock
Penstock Pressure Piping
Butterfly Shut-Off Valve
Differential Piston Oper By-Pass
Operating Cylinder for Butterfly
Flow to Turbine Casing
To 52T
Mech. Oper on Gv. Speed
Turbine Gate Ring
Close
Servomotor
Initial Opening for Starting & Syn. Unit
Turbine Casing Air Valve
110 V. AC. From Station Service T.B
Jack Screw Motor with Reversing Contactors R and L
16" Face plate, 60 step Rheo type
Counter
Float
FOREBAY
SPAULDING P.H. No 1
16" Face Plate 60 step Rheo type actuated by Jack Screw
Tele Line
"RB" Balance Relay
To Master Relay No 3
60 Kv To Spaulding P.H. #1
Station Service Transf. Bank
2200/220 V
Power Transformer 6600/60000 V
Disc Sw. 600 A. 15000 V.
Disc Sw. 600 A. 15000 V.
PT 6600/110 V
C.T. 750/5 A
PT 6600/110 V
Voltage Regulator
Motor Field
Limit Sw.
Main Contactor
Cont. Sw. Close
Cont. Sw. Trip
Jack Screw Motor Control Reversing Contactors
Limit Switches
Contact closed when either Pelton Differential Piston Servomotor or Butterfly Shut-off Valve is in shut-down position. (Limit Switches "E" and "G" on Pelton Layout)
BP1
BP2
BP3
To P.B. "Stop" of Spaulding P.H. #1
C.T. 750/5 A
7000 H.P. 6600 V. 60 Cy. Generator
Water Wheel 450 R.P.M.
Fld Disch
Exc Rheo
Exc 125 V.
Speed Relay
Sh. Fld
Motor Oper Gen Rheo
Exhaust to Atmosphere
LEGEND
Solenoid operated 3-Way Valve Rotates 90° when energized
A - For closing Butterfly
B - For opening Butterfly
C - For opening and closing Turbine Guide Vanes
Limit Switch Closed when actuated
Limit Switch Opened when actuated
Shunt Coil of Relay, Coil or Contactor
Series Coil of Relay or Contactor
Contacts - light or heavy duty
Open when coil is de-energized
Contacts - light or heavy duty
Closed when coil is de-energized
Resistor

Fig. 3. Schematic wiring diagram of Spaulding No. 3 control.

short-circuit around relay 52X it will not allow the oil circuit breaker to "pump" due to any defective mechanism or connection. The oil circuit breaker thus is closed, and latched in the closed position.

The Generator Field is Closed—Immediately after the oil circuit breaker closes, full field current is applied to the generator by connecting it to the exciter which has been allowed to build up in its normal way to approximately full voltage. By referring to the circuit it may be seen that the closing of oil circuit breaker 52 energizes the main control magnet of auxiliary field contactor 41X. The closing of 41X in turn energizes the main control magnet of field contactor 41. The contacts of 41 connect the generator field across the exciter armature. This causes the generator to pull into step, mainly through the action of the amortisseur windings on the rotor, and be held there by the field.

Field Failure—Other auxiliary contacts 52 on oil circuit breaker 52 close to complete circuit through device 40X which has a time delay of about 7 sec. in closing its contacts and which energizes lockout relay 30 and shuts down and locks out the station in case the field current does not pick up in that time. Should the exciter build up, however, and supply current to the field within the 7 sec., field failure relay 40 will pick up and open its "make" contacts to de-energize time delay relay 40X.

If the field fails at any time while the plant is in operation field failure relay 40 will become de-energized. its "break" contacts will be closed energizing time delay relay 40X which, after a period of 7 sec., will proceed to shut the plant down.

The Voltage Regulator—When the oil circuit breaker 52 closes, a "make" contact 52 completes the circuit of the voltage regulator contact-making voltmeter. The regulator then operates through the reversing switches and motor-operated rheostat to maintain constant voltage on the generator.

The high-speed rheostatic voltage regulator 60 is used in this application. The performance of the high-speed regulator parallels that of the vibrating type.

Referring to the forebay load control equipment it may be noted that closing of oil circuit breaker No. 52, through its auxiliary contact, energizes the forebay control line and transfers the control of the type "MC" interposing relay to the balance relay. With the arms of the forebay and station rheostats in similar positions no current will flow to the balance relay, and it will remain in balance. Should the water level change, the float will cause a movement of the arm and current will flow through the balance relay and cause it to close its contacts in one direction or the other, depending upon whether the water level is increasing or decreasing. The closing of one or the other of the balance relay contacts energizes the proper "MC" interposing relay, in turn operating the proper jack-crew motor-control reversing contactor. Thus it may be seen that the jack screw will be moved by the jack-screw motor to a position corresponding to the water level in the forebay and the unit thus will pick up a load corresponding to the head of water available.

Stopping the Generator—Normal stopping of the unit is accomplished by the closing of the push button at Spaulding No. 1, which shorts out master relay No. 3. In dropping out, No. 3 de-energizes No. 65, in turn de-energizing the self-restoring valve "A," "B" and "C," causing the controller differential piston immediately to close to the full shutdown position and trip the oil circuit breaker through limit switch G. Opening of the oil circuit breaker de-energizes the field of the generator, its energy being dissipated by the field discharge resistance. The oil circuit breaker anti-pumping relay 52Y also is de-energized ready for the next start.

It may be noted that master element No. 1 remains energized and thus through its "break" contact in the circuit of master relay No. 3 prevents the station from restarting until such time as the line breaker at Spaulding No. 1 is tripped and the line de-energized, thus allowing No. 1 to drop out.

It may be noted also that when circuit breaker No. 52 is tripped, interposing relay "MCL" is continuously energized to operate the jack-screw motor in the shutdown direction until its circuit is opened by the operation of limit switch J, or by the opening of contact 1 through the de-energizing of the power line. If the a.c. power is cut off before the jack screw reaches the full shutdown position, it will of course be caused to finish its stroke the first thing upon energization of the line for the next start.

De-energizing valves "A" and "B" of course reverses the operation previously outlined, closing both the butterfly valve and the by-pass valve. Through shutdown limit switch "E" the butterfly will operate to trip the circuit-breaker in case the same was not tripped by the operation of limit switch "G'" due to some obstruction in the turbine gates not allowing them to close fully.

Protective Features

The protective features are of two kinds: those which operate device 30 to lock out the unit making it necessary for an attendant to visit the station and reset device 30 before the unit can be restarted, and those which shut down to await being restarted in the normal way.

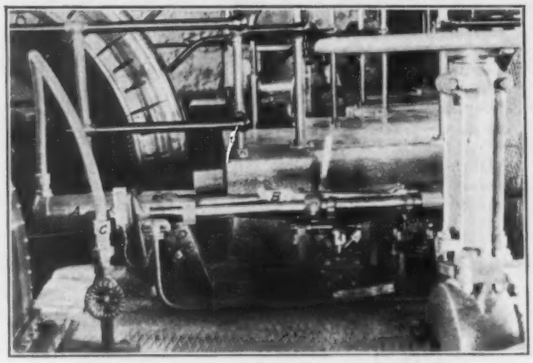


Fig. 4. Automatic shutdown device for Coal Canyon power house, Pacific Gas and Electric Company.

Lockout Protective Features Operating Device 30—The following devices operate lockout device 30:

No. 87. Differential protection on the generator.
No. 51. Over-current on the generator.
No. 16. Control battery discharged.
No. 63. Penstock pressure failure.
No. 38. Overheated generator or exciter bearings.
No. 97. Failure in flow of cooling water.
No. 96. High temperature of machine.
No. 40. Field failure.

All of the above devices, except the first three, are connected through operation indicators on device 30 so the attendant can tell readily which device locked out the station.

Shut-Down Protective Features Operating Device 3—The following devices close contacts which shunt the operating coil of device 3 and shut down the station, but leave it ready to be restarted in the normal way:

No. 49. Overload.
No. 12. Overspeed.
No. 26. High temperature on the power transformers.
No. 47. Undervoltage, single or reverse phase.

Independent Emergency Overspeed Lockout—Mechanical overspeed device.

Differential Protection—Three low-energy overcurrent relays (87) are used to protect the generator from internal trouble. These relays upon operation energize the lockout relay 30 and operate the annunciator 87.

Overload—Overload on the generator is taken care of by two different devices. The first includes the long-time-element thermal relays (49) which will take the equipment out of service providing the machine is overloaded by wattless current or by any serious unbalance of load. The overload relays (51) are set high and are used to take the equipment out of service in case a serious short-circuit or other dangerous line trouble develops outside or inside of the station.

Loss of Control Voltage—As in this case the high-speed rheostatic regulator is used, the exciter is operated at a fixed potential. This means that the resistance (RB) plus the series rheostat form a trickle charge for keeping the 48-volt control storage battery always at the state of full charge. The coil of the amp.-hr. relay (16) measures the small trickle charge into the battery and this charge keeps the contacts against the fully charged position. Should trouble occur in the battery charging circuit the battery will sart to discharge on the normal control load. Therefore, the contacts will start towards the discharge position. After a predetermined number of amp.-hr. have been consumed, the contacts of relay 16 close to energize auxiliary battery charging relay 16X. In picking up, relay 16X makes

contact in the circuit of annunciator lockout relay 30. The point at which relay 16 makes contact must be such that the battery still has enough available energy to perform the locking out operation and trip the oil circuit breaker.

Loss of Penstock Pressure—Penstock pressure failure relay No. 63 will close its contacts at a pressure corresponding to a 250-ft. head, operating No. 30 and thus locking out the station in case the penstock pressure falls to a dangerous point.

Overheated Bearings—In case a generator or exciter bearing reaches a dangerous temperature the proper bearing thermal relay (38) will operate to close its contacts and complete the circuit of lockout relay 30, thus locking out the station.

Failure of Flow of Cooling Water—In the event of failure of cooling water flow on the transformers device 97, a water flow indicator closes its contacts which operates auxiliary relay 97X which in turn operates the lockout device.

High Temperature of Machine—Device 96 is a "CT" temperature relay with its thermal element embedded in the coils of the machine and in event of excessive temperature will, through its contacts, operate lockout relay 30 and shut down the plant.

Loss of Field—In case the generator loses its excitation, field failure relay 40 drops out and makes contact in the circuit to start auxiliary field timing relay 40X to make contact. If the excitation is not restored for a predetermined time, relay 40X will make contact and operate lockout relay 30.

Overspeed—Operation of overspeed contact 12 of the speed relay shorts out master relay No. 3 and causes the unit to be shut down in the same manner as when stopped by operation of the push button at Spaulding No. 1. Should this overspeed protection fail, an added increase in speed of the unit will operate the flyball overspeed trip which hydraulically opens valve "D" (Fig. 1) to drain the larger area end of the controller cylinder, acting independently of the electrically controlled equipment to shut down the station. This device must be reset by hand.

High Temperature of Power Transformer—This device is a temperature indicator which operates an auxiliary relay 26X to shut down the station.

Under Voltage Single or Reverse Phase—A "CP" single or reverse-phase relay which will not close its contacts on less than 85 per cent voltage. It will shut the plant down by acting directly on the circuit to the master relay in event of reverse phase or phase failure or in case the voltage drops to 65 per cent of normal.

Underspeed—The underspeed contact 14 of the speed relay insures that the generator is at standstill or running at a speed below approximately 90 per cent before the unit may be started.

Overvoltage—In case overvoltage occurs, a.c. overvoltage relay 59 makes contact and causes field changing relay 93 to open. As relay 93 opens it inserts a resistance in the exciter field rheostat thus temporarily reducing the exciter voltage and hence the generator excitation. The same sequence occurs when exciter overvoltage relay 45 picks up and makes contact.

Starting Protection—Auxiliary field timing relay 40X also acts to lock out the unit in case it is not connected to the line within a pre-determined time. Since the contact of 52 is open, all of the resistance R40X is in the circuit and a long time interval, usually 20 sec., is given to allow for normal synchronizing as the circuit breaker closes. Relay 40X is recalibrated to a shorter time for field failure protection by the shorting out of a part of its series resistance through an auxiliary contact on the circuit breaker No. 52.

Device No. 1 Master Element—This is used for the purpose of preventing the station from immediately re-starting after one of the shut-down protective features (not lockout) has operated.

Station Service—It may be noted that station service circuit breaker No. 152 is closed only by the operation of control switch CS which is manually operated. The same anti-pumping features are provided as for circuit

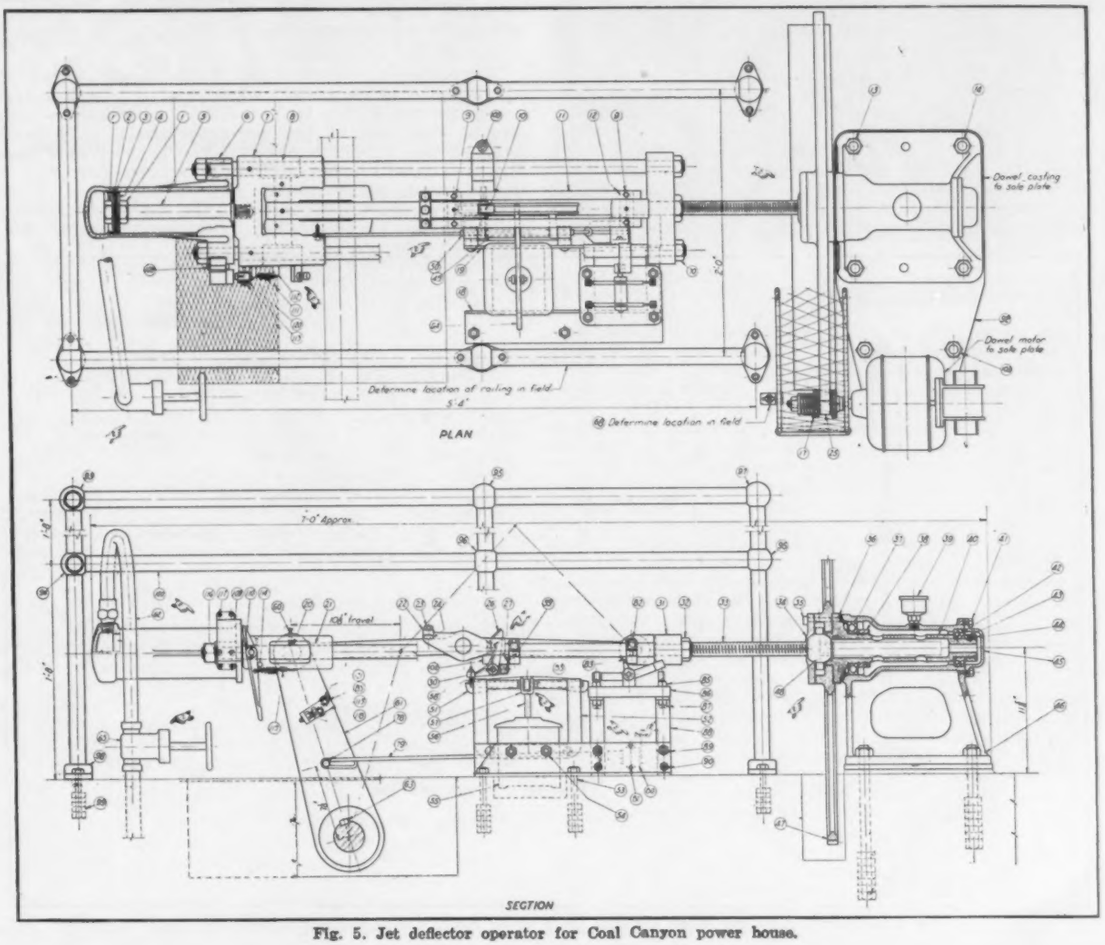


Fig. 5. Jet deflector operator for Coal Canyon power house.

breaker No. 52. Tripping of feeder breaker No. 152 is accomplished only by operation of the control switch in the trip direction, or by operation of a.c. overcurrent relay No. 151. Thus it will be seen that internal station trouble on this feeder will trip No. 152, in turn cutting off the a.c. supply to the valve solenoids and thus shutting down the station in case it is in operation.

Preceding Developments

In the design of Spaulding No. 3 power house advantage was taken of experience gained through the design and operation of other plants in the system of the Pacific Gas and Electric Company which were converted for semi-automatic operation. The Spaulding No. 3 automatic controller especially is the direct result of the development of two other similar devices. A brief mention of these may be of interest because of the development so clearly brought out.

Coal Canyon Power House—The equipment consists of a 2.3-kv., 1,000-kva. generator directly connected to impulse wheels of combined capacity of 1,400 hp. operating under a head of 350 ft. There are two impulse wheel units, one on each end of the generator shaft. Each unit is made up of two impulse wheels under the same hood. The plant was governed by a governor acting upon jet deflectors. The nozzles were stationary type without needles.

The plant required three operators and a foreman whose time was divided between Coal Canyon and Lime Saddle. Operating expense was high in proportion to the plant output. It was estimated that nearly 60 per cent of the operating expense could be saved by converting the plant for semi-automatic operation. An automatic controller and shut-down device was designed and built by the Pacific Gas and Electric Company to replace the governor. One nozzle of each pair was replaced by a motor-driven needle-type nozzle.

The shut-down device (See Fig. 4) operates the jet deflectors. It consists of a hydraulic cylinder (A) connected permanently to penstock pressure through metallic hose (C). The piston is connected through rocker arm (D) to the deflector rock shaft below the floor. The piston also is connected to toggle linkage which breaks at (B). The other end of the toggle linkage is connected at (F) to a jack screw (E) which is driven by an induction motor. The position shown in the picture is that of normal operation with the plant carrying load. Hydraulic pressure is applied at the end of cylinder (A). If the automatic devices operate to shut down the plant, the tripping mechanism below (B) releases a catch allowing hinge point (B) to describe an arc vertically about point (F) as a center. Rocker arm (D) moves to an angular position to the right side of the vertical, driven by the piston in cylinder (A) and lifting the deflectors into the jets to shut down the wheels. The device is reset by backing the jack screw away with the motor, carrying with it point (F) until the toggle mechanism is restored to its approximately straight-line position and latched. The motor then reverses and drives the jack screw back exerting forces through the reset toggle to the piston and rocker arm, restoring them to the position shown in Fig. 4 and Fig. 5.

Coal Canyon, similar to Spaulding, receives its water from the end of a ditch 12 miles in length. There being no forebay capacity the plant load is controlled by the water supply. The first float-control system installed was not a success. The principal trouble was caused by the fact that the needle nozzles over-traveled in both directions causing a periodic swing or hunting action. There was too great an interval between the opening and closing of the float switches which allowed the needles to over-travel considerably. There was no compensating action such as is employed in waterwheel governors and such a feature would have been very difficult to include. The device was replaced by the Spaulding No. 3 type which already has been described. This has given very satisfactory results.

This plant is semi-automatic in its operation. There is an attendant living in a nearby cottage who starts, synchronizes and places the unit on automatic control. He then leaves the plant to operate itself. In the event of serious trouble the unit will shut down and sound an alarm in his cottage. The attendant investigates the nature of the trouble and if there is nothing to prevent his doing so, he puts the unit back into operation.

Deer Creek Power House—The next stage in the development of equipment for automatic plants of the Pacific Gas and Electric Company may be seen at Deer Creek power house, Fig. 6. At this station the differential hydraulic cylinder was substituted for the combined hydraulic cylinder and toggle linkage used at Coal Canyon. Figure 6 illustrates diagramatically the operation of this device and is self-explanatory. The station operates similar to Coal Canyon in that it is semi-automatic with an attendant residing near the station to place the unit in operation.

The plant has just been converted for semi-automatic operation. The equipment consists of a 6,875-kva., 2.3-kv. generator driven by two 5,225-hp. impulse wheels, one on each end of the generator shaft. The static head on the wheels is 837 ft. The nozzles were hand operated needle types. They have been converted to motor-driven, automatically controlled needles. There was a governor which controlled the speed by raising or lowering the nozzle bodies. This governor has been

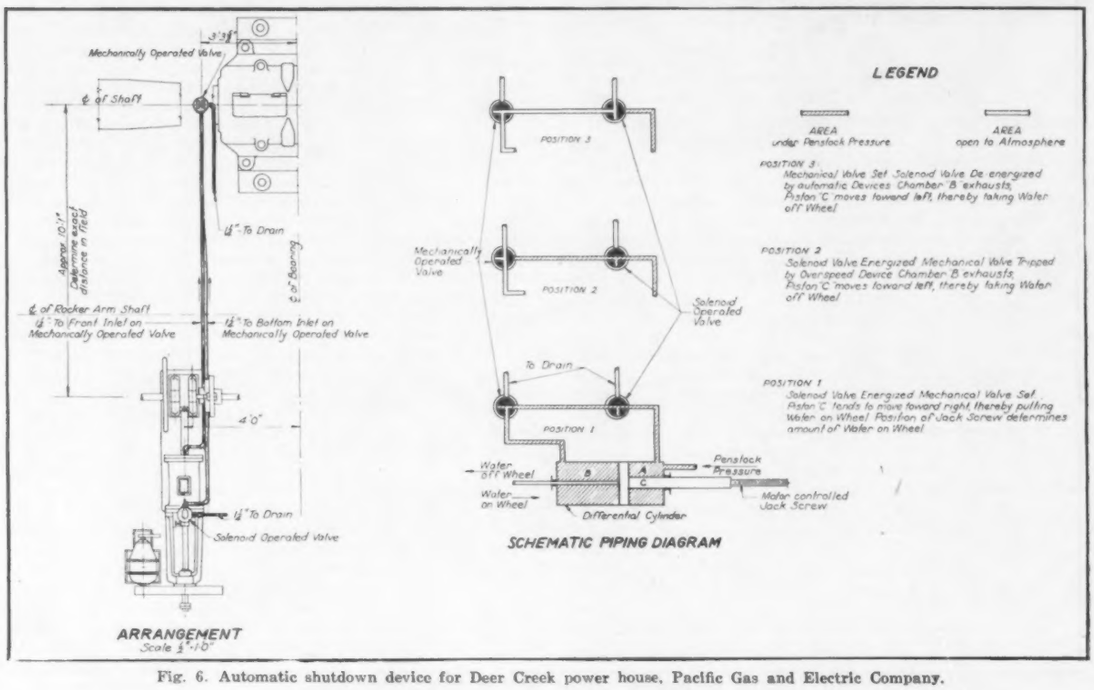

Mechanically Operated Valve
℄ of Shaft
Approx. 10'-1" Determine exact distance in field
½" To Drain
2'-0" Bearing
℄ of Rocker Arm Shaft
½" To Front Inlet on Mechanically Operated Valve
½" To Bottom Inlet on Mechanically Operated Valve
4'-0"
½" To Drain
Solenoid Operated Valve
ARRANGEMENT
Scale ½"=1'-0"
LEGEND
AREA under Penstock Pressure
AREA open to Atmosphere
POSITION 3
Mechanically Operated Valve
POSITION 2
Solenoid Operated Valve
To Drain
POSITION 1
Water off Wheel
Water on Wheel
B
A
C
Penstock Pressure
Motor controlled Jack Screw
Differential Cylinder
POSITION 3: Mechanical Valve Set Solenoid Valve De energized by automatic Devices Chamber B exhausts, Piston C moves toward left, thereby taking Water off Wheel
POSITION 2: Solenoid Valve Energized Mechanical Valve Tripped by Overspeed Device Chamber B exhausts, Piston C moves toward left, thereby taking Water off Wheel
POSITION 1: Solenoid Valve Energized Mechanical Valve Set Piston C tends to move toward right thereby putting Water on Wheel Position of Jack Screw determines amount of Water on Wheel
SCHEMATIC PIPING DIAGRAM

Fig. 6. Automatic shutdown device for Deer Creek power house, Pacific Gas and Electric Company.

replaced by the differential hydraulic cylinder type (Fig. 5) acting upon the nozzles as a shut-down device.

Operating Experience

Coal Canyon has been in successful operation as a semi-automatic station for more than a year. Deer Creek is about to be put on the line at the date of this report (December, 1927). Spaulding No. 3 has not yet been placed in operation. The equipment, however, has all been manufactured.

Experiences at Coal Canyon brought out one point that should be emphasized. Any automatic equipment, if left without attention for extended periods of time, eventually will become stiff, "gummed up," or clogged in such a manner that it may fail to function when called upon. The equipment, therefore, should be inspected and cleaned and frequently tested by an attendant.

Coal Canyon had been operating on semi-automatic control for about three months without a periodic test of the shut-down equipment. The plant was visited for the purpose of deliberately shutting it down to test out its operation. The unit was tripped, whereupon the shut-down device failed to operate. The plant was put back in service and again tripped. The operation the second time was perfect. The operation was repeated several times without any duplication of the failure experienced the first time. It was assumed that in this case the trouble was caused by the accumulation of trash over the entrance of the pipe which supplies pressure to the hydraulic shut-down cylinder. Resetting the equipment expelled water from the cylinder into the penstock, carrying away the obstruction. This explains the failure to operate the first time without any succeeding failure.

It emphasized the need of a good strainer for water used in automatic shut-down equipment, and also emphasized the advisability of establishing a periodic inspection and actual operating test of automatic equipment to the extent of actually shutting down the station and putting all protective equipment through its normal operation, thereby preventing corrosion and sticking because of unuse. A regular weekly test of the equipment has been established at Coal Canyon with the result that to date there have been no failures and therefore nothing for further comment.

Developments in Automatic Hydraulic Equipment

By R. S. Quick*

This paper is limited to a discussion of the design and application of automatic control and operating devices to hydro equipment for constant-frequency electrical systems. The principal schemes of operation developed in recent years in the application of automatic equipment are mentioned.

Classification of Plants

Hydro-electric plants may be classified as either base-load or governing, although the conditions of operation may change from one to the other at a given plant. The base-load plant operates directly with stream flow in cases where forebay capacity is limited or water rights prevent storage, or regulates the flow from a primary storage reservoir into a series of downstream plants.

Governing plants, whose ouput is controlled by the frequency of the system, usually operate from storage since otherwise the natural stream flow would not fit the load properly at all times.

Types of Automatic Control

Automatic hydro plants are classified as either partial or full-automatic, both being subject to certain local or remote-control supervision. Partial-automatic plants are those which must be started and synchronized by local manual service, but which are loaded and shut down automatically. Full-automatic plants are those designed to start and synchronize automatically once the starting indication has been given. Both are subject to local or remote control depending upon operating conditions.

Every hydro-electric plant is partial automatic in some respect. For example, the forebay takes care of the difference between the rates of inflow and outflow while the speed governor adjusts the load under control of the system frequency. Lubrication of the bearings and the oil pressure system of the governor likewise are automatic in operation. However, for the purpose of this discussion, the plant is not considered even partial-automatic unless certain special control or protective features, not otherwise provided, are used. It is obvious that adequate inspection and maintenance must be employed to keep automatic apparatus in proper working condition at all times for reliable service.

Conditions Favoring Automatic Operation

Conditions favoring automatic operation are economic and special. In plants of medium or small output, particularly those which are isolated or inaccessible during the winter months, the capitalized value of the saving in operating costs usually is more than ample to cover

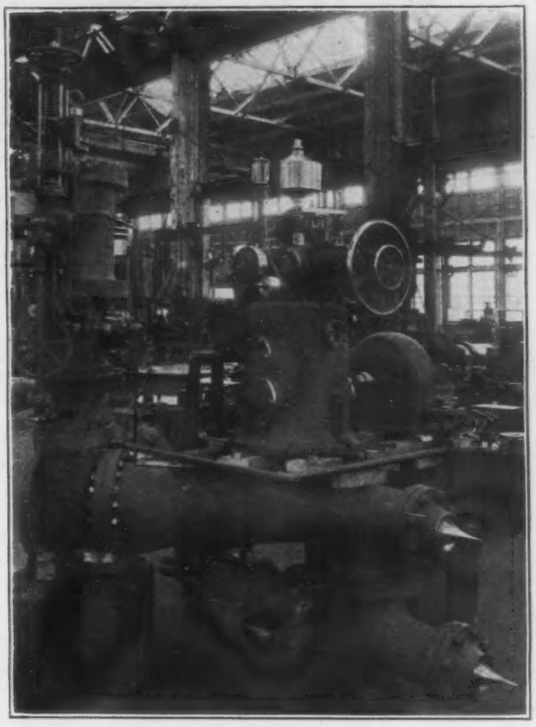


Fig. 1. A shop assembly of the penstock valve, main power and relief nozzles, and governor for the full automatic Ruxton plant.

the added investment. This applies to the original construction of new plants and to the conversion of old ones as well. The special conditions favoring automatic operation are those which could not be taken care of so satisfactorily even by skilled operators. The standard oil-pressure governor which adjusts the load for a constant system frequency is a good example. Not only does it follow speed variations more quickly and closely than any operator could, but also it takes care of emergency shutddown conditions following separation from the system where a runaway otherwise would result. This same thought may be extended to forebay float devices which maintain the outflow and inflow of stream flow plants within satisfactory limits and without wasting any of the normal quantity of water.

A great many existing stream-flow plants of moderate capacity have been converted to partial automatic control, arranged for manual starting and synchronizing by the caretaker and then left to run on block load under control of a forebay float device, shutting down in case of trouble or on signal from the point of supervision. Another type of automatic installation is that controlling the outflow from the primary storage reservoir through a system of stream-flow plants below. In this case the plant has been made full-automatic so that the outflow may be adjusted to suit the water quantity required by the other plants of the chain. Such units, as a rule, have been provided with speed governors whose setting is determined by remote supervision of the synchronizing or load-control motor. A separate load limit as well is used to limit the maximum opening.

* Report of subcommittee of hydraulic power committee.

Thus the conditions favoring automatic operation depend upon the circumstances and in one case may be purely economic while in another may be required for special reasons to maintain the quality and degree of reliability of service which manifestly would be impossible under manual control.

Types of Apparatus and Application

The gate-opening regulating mechanism of the impulse wheel or reaction turbine should be operated with automatic controls in much the same fashion as with

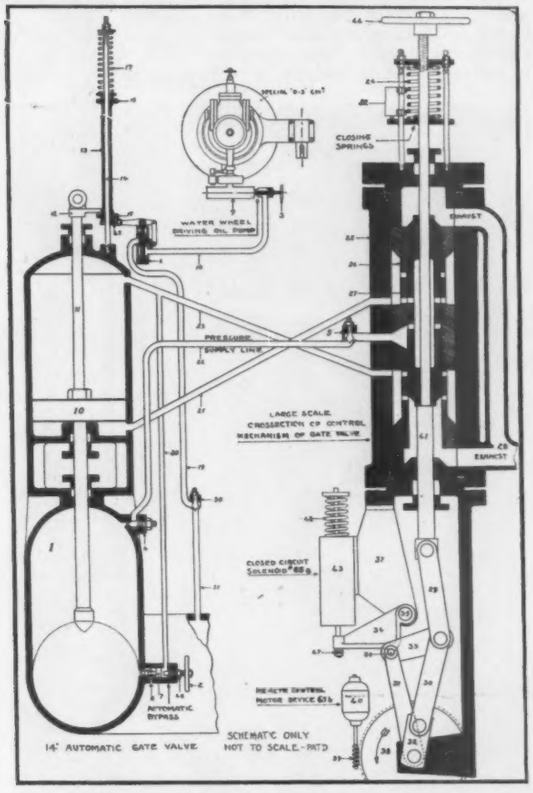


Fig. 2. Schematic layout of the equipment shown in Fig. 1.

manual operation, taking care to limit pressure surges, wasting of water and overspeed. When a speed governor is employed the devices added usually consist of:

A remote-controlled synchronizing or load-control motor.
A remote-controlled gate-opening or load-limit device.
A solenoid-controlled spring-operated latch to cause shutdown in case of internal trouble.
A mechanical overspeed trip to supplement the electrical controls.
A solenoid controlled hydraulically operated penstock shutoff valve arranged to open only after the downstream conduit has been primed properly through the bypass. Protection of main bearings against overheating.
Protection against loss of governor oil pressure.
Protection against loss of penstock pressure.

When the plant operates on block load at all times, the governor and oil pressure system may be replaced advantageously by a penstock operated hydraulic controller with suitable load limit. This device is more reliable than a governor since pressure to operate it is always available so long as the penstock is full and otherwise could start the unit in case the gate should drift open. This controller can be provided with devices to permit starting the unit automatically as well as controlling the output and shutting down.

Relief valves or nozzles used to limit the penstock pressure rise in water economizing plants should be so mechanically interlocked with the gate closure mechanism as to present rapid shutoff effectively in case the opening of the relief valve should be obstructed due to any cause whatsoever.

In selecting the automatic control and protective features of the hydraulic power equipment the principle should be followed that every single device should be supplemented by another so as to insure complete shutdown in case of the failure of either, but of course not of both simultaneously.

Thus, the needle-nozzle can be arranged to supplement the deflector while the penstock shutoff valve can be designed to close upon failure of the deflector, needle-nozzle or guide vanes. The mechanical overspeed device supplements failure of the electrical overspeed trip and the mechanism which it operates. This same thought or principle should be applied to every device employed.

In all governor or controller-operated needle-nozzle or guide-vane installations an automatically operated main shutoff penstock valve becomes an essential element of the equipment. It must be capable of closing without objectionable vibration, chatter or pressure rise in the penstock and against full-load flow or even spouting-velocity under emergency conditions brought about by failure of the normal shutoff devices or of the downstream intervening conduit. The types of valves adapted to such severe service are the needle, butterfly and special designs of disc gates. This valve should close at a slower rate than the needle-nozzle or wicket gates under normal conditions so as finally to shut off with pressures balanced and thus reduce penstock disturbances to a minimum. Likewise, the penstock valve should not open upon starting the plant until the downstream conduit has been primed properly through the bypass. There are other types of valve which may be designed for this service but the three above mentioned are the principal types applied to date in Pacific Coast installations.

Since the hydraulic controller does not have any centrifugal speed element similar to that of the standard governor, it is desirable that a mechanical overspeed device of dependable design and operation be connected directly to the gate operating mechanism. Many interesting developments are being made along these lines.

The oil-pressure governor uses an isolated fluid medium free from sediment, corrosive tendencies and possessing excellent lubricating qualities. Devices using penstock water must be designed for thoroughly reliable operation in the presence of suspended sediment, considerable corrosive tendencies and in the absence of practically all lubricating properties.

The sequence of operation of the hydraulic control apparatus should be positive and so interlocked as to prevent any abnormal condition resulting in danger to

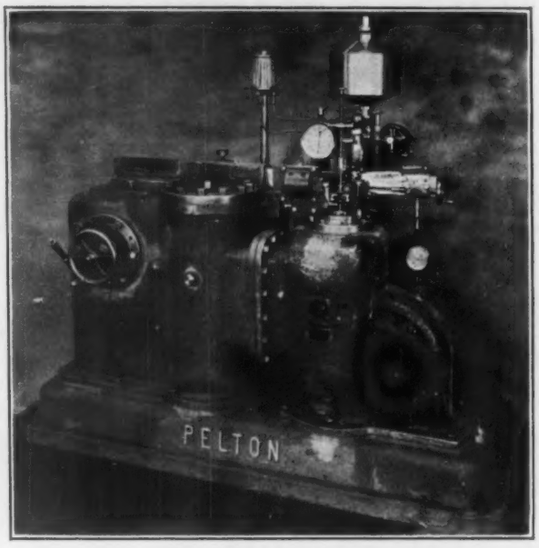


Fig. 3. Governor actuator for Glines Canyon plant.

the plant or system. The methods developed for taking care of these requirements are shown in the accompanying illustrations.

Ruxton Plant

In Fig. 1 is shown the shop assembly of the penstock valve, main power and relief nozzle, and hydraulic governor for the full automatic Ruxton Park plant of the City of Colorado Springs, built in 1925. The waterwheel develops 1,450 hp. at 514 r.p.m. under 1,000-ft. working head. The penstock is 20 in. in diameter and slightly more than 11,000 ft. long and under a static

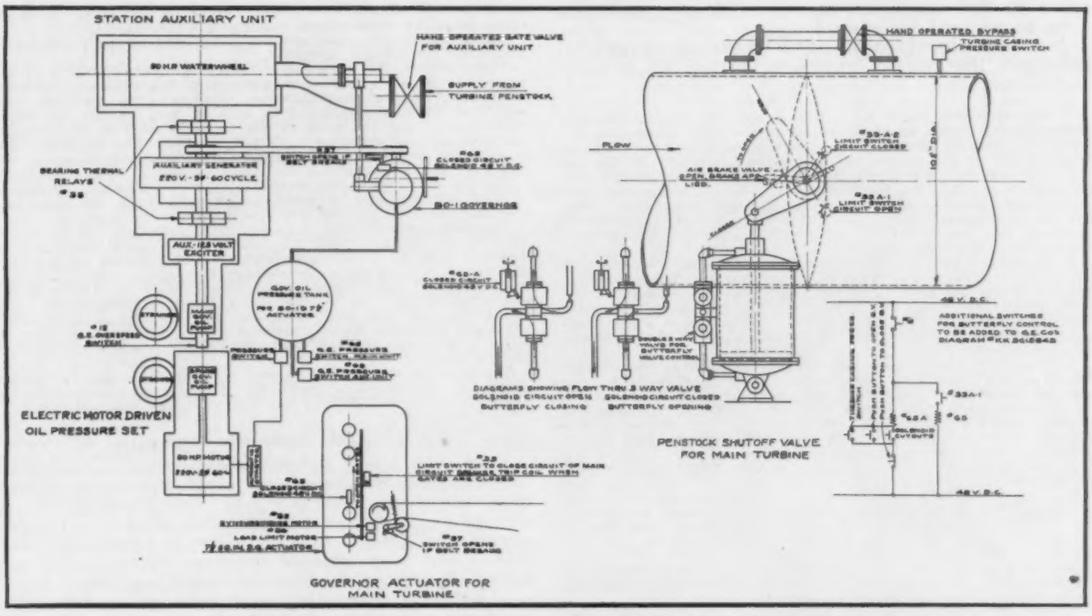

STATION AUXILIARY UNIT
HAND OPERATED GATE VALVE FOR AUXILIARY UNIT
SUPPLY FROM TURBINE PENSTOCK
AUXILIARY GENERATOR
BEARING THERMAL RELAYS
AUX. 125 VOLT EXCITER
GOV. OIL PRESSURE TANK
ELECTRIC MOTOR DRIVEN OIL PRESSURE SET
HAND OPERATED BYPASS
TURBINE CASING PRESSURE SWITCH
FLOW
PENSTOCK SHUTOFF VALVE FOR MAIN TURBINE
ADDITIONAL SWITCHES FOR BUTTERFLY CONTROL
GOVERNOR ACTUATOR FOR MAIN TURBINE

Fig. 4. Schematic diagram of hydraulic control equipment of the Glines Canyon plant.

head of 1,160 ft., originating in Lake Moraine which is one of the principal storage reservoirs of the City of Colorado Springs water system and at an elevation of more than 10,000 ft. on the southern slope of Pike's Peak.

This unit is controlled over about 2½ miles of aerial line from the Manitou power house slightly more than 2,400 ft. below. The Manitou installation was made in 1903 and is described in Electrical World of May 26, 1906. Being under a static head of 2,416 ft., it is one of the pioneer high-head installations of the United States.

The operation of the governor and penstock valve are so interconnected that the bypass must open to prime the nozzle body and the gate valve open before the main power nozzle opens. This insures the standard manual sequence and prevents the possibility of objectionable water-hammer and wear of the gate-valve disc. Normal shutdown takes place in 3 sec., the auxiliary relief nozzle limiting the pressure rise to about 10 per cent above static head accompanying full-load rejection. The gate valve then closes slowly with pressures balanced. Under emergency conditions, however, it can shut off against full flow, should the main or relief nozzle fail to close for any reason.

1. To start the plant device No. 65, which consists of solenoid 43 and motor 40 in parallel, is energized by remote control. This moves gate-valve control mechanism from the "closed" to the "open" position, against the compression of closing springs No. 24. At the end of the opening stroke, toggle and trigger 36 being engaged, the motor is stopped by limit switch 52. This exhausts penstock pressure from the top of the gate-valve cylinder and allows automatic bypass No. 7 to open thus filling closed needle nozzle body.

2. Gate valve moves slowly open with pressures balanced. Near the end of the stroke tailrod arm No. 12 opens penstock pressure supply to watewheel-driven oil pump.

3. Governor oil pump delivers pressure direct to the control valve which, with the belted centrifugal head at rest, causes the governor to open the main needle and the unit to accelerate.

4. At about 95 per cent normal speed the generator is connected to the line without field, followed by fully synchronizing in the normal manner employed with that method.

5. The unit is loaded by remote control of the synchronizing or load-control motor on the governor, the maximum opening being limited by a hand-operated load limit which is set from time to time to suit the outflow desired.

6. Normal shutdown is accomplished by first rejecting the load with the load-control motor so as to reduce the shock on the system, followed by de-energizing solenoid No. 43 which allows the closing springs to drop the gate-valve control menchanism.

7. When the gate valve starts to close the water supply is cut off from the waterwheel-driven oil pump thus making the governor inoperative and allowing the heavy closing springs on the main nozzle to push and hold the main power nozzle shut. The gate valve closes at a slower rate and thus completes its shutdown in still water. In an emergency the gate valve is capable of shutting donw against full flow without producing objectionable pressure rise in the penstock should the nozzles fail to close due to an obstruction. When the gate valve reaches full closure, full penstock pressure builds up in the top of the cylinder and closes the automatic bypass thus completing the shutdown.

The closing springs on the main power nozzle protect the hydraulic equipment against loss of governor oil pressure and loss of penstock pressure. The mechanically connected auxiliary relief nozzle provides for water-economizing operation of the main nozzle and protects the penstock against objectionable pressure rise in case of sudden loss of load.

Troubles within the station, such as hot bearings, overspeed or generator difficulties, de-energize No. 43 solenoid which starts the shutdown as previously mentioned.

Figure 2 shows a schematic layout of the equipment shown in Fig. 1 indicating the method of operating the gate valve, forebay, watewheel-driven governor oil pump, etc.

Glines Plant

In Fig. 3 is illustrated the governor actuator for the Glines Canyon hydro-electric unit. It controls a turbine having a maximum output of about 20,000 hp. at 225 r.p.m., under 190-ft. head, and is controlled by supervisory system from about eight miles distance. The auxiliary service unit in the power house, consisting of an 80-hp. 300-r.p.m. waterwheel also is automatic. The schematic layout of the Glines plant is shown in Fig. 4.

The output of the Glines unit is slightly greater than 50 per cent of the system capacity. For the present it is operated partial-automatic with an attendant at the plant to take care of the starting of both the main and auxiliary units. From an engineering standpoint, however, it would be a simple matter to convert the equip-

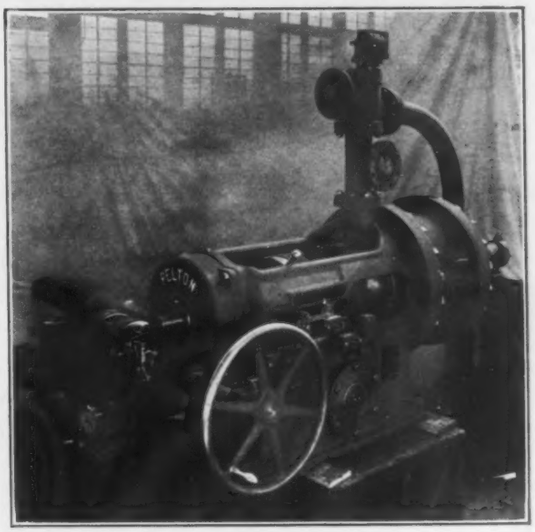


Fig. 5. A 20,000-ft.-lb. servomotor operating directly on penstock pressure at Spaulding No. 3 plant of the Pacific Gas and Electric Company.

ment to full-automatic operation should conditions arise to warrant the change.

Assuming the entire plant to be shut down and de-energized, the general scheme of starting up is about as follows:

1. The attendant starts the auxiliary unit by opening the governor-operated needle by hand control in the same manner as followed in a manual plant. This starts the main governor oil pump which begins to charge the governor oil-pressure tank of the station. Having energy available from the auxiliary generator it then is possible to start the electric-motor-driven air compressor (not shown) and secure an added supply for the oil-pressure tank. When No. 63 oil-pressure switch has closed at minimum pressure the auxiliary unit can be placed on governor control. The electric-motor-driven oil-pressure set is a spare and ordinarily is not used.

2. Having oil pressure and energy available, the attendant now opens the supply to the main governor actuator thus admitting pressure oil to the gate mechanism and holding the latter in the fully closed position. He then opens the bypass of the main butterfly valve thus filling the turbine casing up to some intermediate pressure determined by the leakage through the gates and the bypass capacity.

3. Since the main unit is synchronized at Elwha, the remote-control station some eight miles away, the attendant waits for the operator to close No. 4 contactor by supervisory control. After this is done the attendant operates the push-button to complete the circuit through solenoid 65-A which controls the opening of the butterfly valve. When the butterfly starts from its full shutoff position it first releases the generator air brakes and opens the limit switch No. 33-A-2 in the tripping circuit of the main generator breaker. When the butterfly reaches practically wide open position it closes limit switch 33-A-1 which completes the circuit to solenoid No. 65 on the main governor control valve thus allowing the latter to move freely. Since the belted centrifugal head is at rest the guide vanes open with oil pressure and the unit accelerates. The generator breaker closes by solenoid action thus placing generator on the line to Elwha where the final synchronizing takes place. The attendant then closes the butterfly bypass and checks up on the equipment in general.

4. The output of the unit is controlled by supervisory system using the load-limit and speed-control motors on the governor.

5. The lubricating oil system of the generator and turbine is taken care of automatically by an electric-motor-operated oil-pressure system which starts up with the auxiliary unit, supplemented by a direct-driven oil-pressure pump geared to the main turbine shaft.

Shutdown under normal conditions is accomplished by first removing the load from the unit by remote control, followed by dropping out No. 4 contactor which de-energizes the solenoids of the main governor pilot valve and penstock butterfly control. The gate mechanism makes a rapid closing stroke with oil pressure tripping the generator breaker with limit switch No. 33. The butterfly makes a slow closing stroke operating the limit switches previously mentioned in reverse order and finally applying the generator air brakes when practically shut off.

Protection against hot bearings, loss of oil pressure, overspeed, etc., is accomplished in the usual manner by dropping out No. 4 contactor and causing shutdown as above described.

To prevent the butterfly from closing and shutting down the plant in case of a momentary opening of No. 4 contactor the turbine casing pressure switch parallels the cutout of solenoid 65-A, providing the casing pressure is not below the minimum for which the switch is set.

The primary switch of the spare electric-motor-driven oil-pressure set is closed after the plant is in service so that it may start up by automatic pressure-switch control should the main oil pump driven by the auxiliary unit fail for any reason.

The generator air brake pressure is adjusted carefully and maintained for the proper operation.

The auxiliary unit continues to run even upon shutdown of the main unit so as to furnish station energy and maintain governor oil pressure for prompt starting. However, the auxiliary unit will shut down automatically in case of local trouble for which protection is required, such as hot bearings, drop in oil pressure, governor belt breakage or electrical trouble. The auxiliary unit is arranged to synchronize automatically with the station a.c. bus whenever the output of the main unit reaches a certain minimum value, the switching being controlled by a power relay. Shutdown of the auxiliary unit is accomplished entirely by the governor-operated needle-nozzle, the gate valve being hand operated.

The main butterfly valve is a part of the automatic control system since it was believed that the turbine guide vanes could not be depended upon for a sufficiently tight shutoff to insure bringing the unit to rest. Leakage water through the runner would cause the unit to idle at some partial speed which would make difficult the proper application of the generator brake. Furthermore, any foreign obstacle such as a log might lodge between adjacent guide vanes and effectively prevent shutdown. The butterfly valve can be closed against full penstock flow and thereby becomes a safeguard for the plant.

The scheme of operation above outlined is subject to minor changes to suit operating conditions. The plant has been in service since the spring of 1927 and has been operating satisfactorily.

Automatic Hydraulic Controller

Shop assembly of the automatic hydraulic controller for Spaulding No. 3 plant of the Pacific Gas and Electric Company is shown in Fig. 5. This is a 20,000-ft.-lb. servomotor using penstock pressure directly. It is a combination quick-acting hydraulic shutdown and load control and is capable of handling full-automatic sequence of starting, loading and shutdown.

In Fig. 6 is shown the cross-section of an automatic hydraulic controller. It is a complete gate-operating mechanism using penstock pressure direct, with combination quick-acting shutdown and electric-motor-operated load limit, developed as a simplified substitute for the conventional oil-pressure governor for application to block-load units. It is capable of starting, synchronizing, loading and shutting down a unit with properly interlocked sequence of operations by controlling the gate opening. The usual oil-pressure system is entirely absent, the pressure fluid being the penstock water taken direct through suitable strainers. It has no centrifugal head as such and therefore uses a reliable mechanically operated centrifugal overspeed trip to insure shutdown on runaway following failure of the electrically controlled solenoid valve or its accessories.

It is considered best practice in the normal shutdown of units using the hydraulic controller or standard governor to reduce the output of the plant to zero before

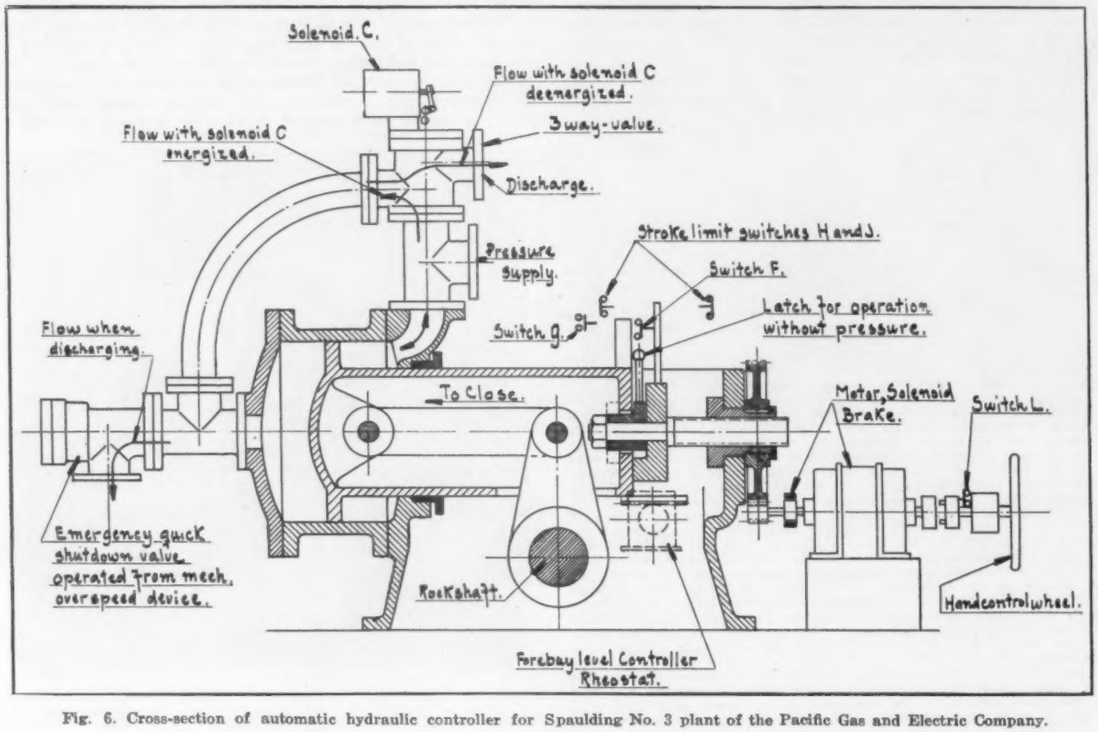


Fig. 6. Cross-section of automatic hydraulic controller for Spaulding No. 3 plant of the Pacific Gas and Electric Company.

the generator breaker is tripped. This reduces overspeed, system disturbances and switch duty. However, upon separation under load in case of trouble which would open the breaker immediately, the quick-acting shutdown feature will reduce the overspeed to about the same value as experienced with the standard oil-pressure governor under similar conditions.

The features which this hydraulic controller possesses for automatic plant application are:

Prevents opening of the gates from full closure until the load limit has been closed to the gate position for acceleration of the unit on starting.

Gate opening limited by load-limit position to just sufficient water for starting and acceleration to normal speed until unit is fully synchronized.

Load-limit permits opening the gate mechanism after closure of generator breaker to any position as determined by its control, such as a forebay float device, output or other deciding factor.

Produces sudden gate closure similar to that of standard governor when solenoid control valve is de-energized or the overspeed trip operates. The gates cannot be opened again until load-limit has closed down to idling position.

A hand-operated mechanical interlock between piston and load-limit to permit straight electric-motor-operated gate mechanism for emergency service, supplemented by a self-locking hand-control mechanism to be used when the motor is out of service and so arranged that the hand-wheel must be disengaged before the motor can be used again.

Since the penstock pressure water carries sediment, has corrosive tendencies and lacks lubricating qualities, all submerged portions of the controller mechanism have been selected with due regard to these problems so as to eliminate the probability of leakage or sticking which might render the device unreliable in operation.

Conclusion

It is hoped that the above principles will assist those interested in applying automatic control and operation to existing or new hydro-electric plants. The required conditions of operation should be considered first and established and then the equipment selected to perform the desired results. The actual physical equipment may take many forms but in general the final scheme embodies apparatus which will follow the sequence of the manually operated plant, interlocking its operation step by step in the proper sequence and at all times maintaining protection to prevent damage to the plant or system in case troubles should arise.

Automatic Hydro Plant Control*

There has been no recent development of any new sequence and protective relays for automatic hydro-electric switching equipment. Induction type relays are used throughout for protection and timing operations. Standard industrial control equipment such as control contactors are used in the sequence for various operations.

Automatic Switching Equipment

Recently a new "speed-matching" unit has been developed for use in automatically synchronized stations in conjunction with the automatic synchronizing device. This speed-matcher consists of two motors operating through a differential for matching the speed of the machine, or the frequency, with that of the line or system. This is the first operation to perform in automatically synchronizing a generator to the system. When the speeds are matched the automatic synchronizing element determines when the machine is in synchronism and closes contacts which in turn causes the oil circuit breaker to close.

The new development consists of mounting the speed matcher on one certain type of waterwheel governor. The usual synchronizing motor is omitted from the full-automatic oil-pressure governor and the speed-matcher operates directly on the governor to increase or decrease the speed of the machine. On equipment using other governors the speed-matcher will be a part of the switching equipment and mounted on the switchboard on the same panel with the automatic synchronizer as shown in Fig. 1.

The speed-matching equipment, when mounted on the governor, consists of two small polyphase synchronizing motors geared together through a differential. This whole assembly is mounted on the governor in place of the usual synchronizing motor and the differential shaft is geared to the governor in such a way that motion of the shaft will operate on the governor to change its setting in a manner similar to the usual synchronizing motor.

When the speed-matching equipment is mounted directly on the governor the operation is as follows:

One of the synchronous motors is connected to the secondaries of the bus potential transformers while the other is connected to the machine transformer. It is evident that these two motors will run at synchronous speed and that the relative speed of the two motors will depend upon the difference in frequency between the bus and the machine. Since the two motors are geared together through a differential and the motors are running in opposite directions, the differential shaft will turn at a rate directly pro-

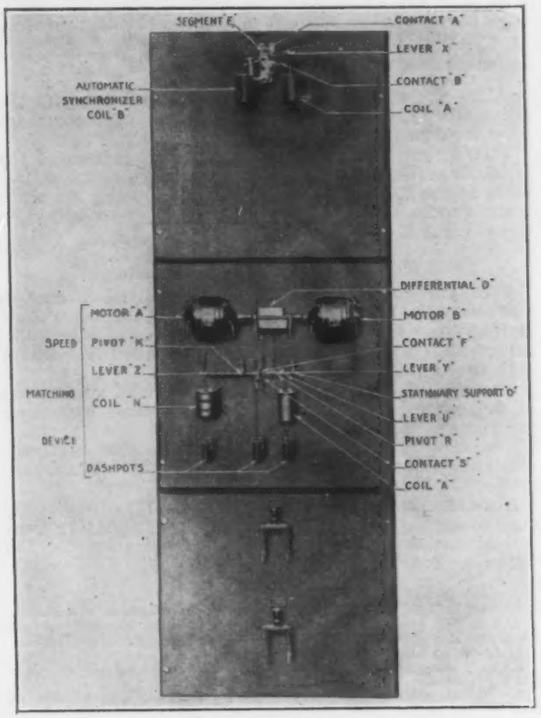


Fig. 1. Panel view of automatic synchronizer.

Fig. 2. Automatic equipment installed on governor.

* Report of subcommittee of hydraulic power committee—P. B. Garrett, H. S. Warren, W. L. Winter.

portional to the difference in speed between the two motors. If the speed of the incoming machine is too high the differential shaft will turn in one direction, while if the speed is too low it will turn in the opposite direction. The motion of the differential shaft is transmitted to the governor speed-control spring in such a manner that the speed of the incoming machine will be increased or decreased until it is exactly equal to the frequency of the bus. When both frequencies are the same the differential motors will be running at the same speed with the result that the differential remains stationary. The adjustment on the governor thereby is made in direct proportion to the difference in frequency and has no tendency to "overshoot." As soon, then, as the frequency has been matched the only delay will be in waiting for the synchronizer to close its contacts thus indicating the "in phase" position.

After the oil circuit breaker has been closed by the automatic synchronizer the speed-matching motors are used for load adjustment.

Fig. 2 shows the new Dalecarlia station of the U. S. War Department. This station consists of two units and is full-automatic in operation, using the automatic synchronizer and the speed-matchers mounted on the governors.

Supervisory Control Equipment

The synchronous-visual type of supervisory control equipment is applicable principally to the control of metropolitan substations where a relatively large number of apparatus units are to be controlled and where high speed of operation is required.

The medium-frequency type has its chief application in the control of high-tension loop systems extending over considerable distances.

The direct-wire type is applicable to the relatively small distribution substations and small railway substations.

For the remote supervisory control of hydro-electric generating stations, the audible type supervisory control is the desirable type for this application for the following reasons:

1. Lost cost
2. Can be used on existing 2-wire magneto telephone circuit
3. One to seven stations may be operated in parallel on one telephone line
4. Least amount of equipment required
5. Very dependable in operation using standard telephone relays and equipment
6. One dispatching equipment may be used for any number of lines at one point.

The audible type supervisory control usually is supplied to perform the following operations:

1. Start and stop the waterwheel-driven generator
2. Increase and decrease the gate opening on the waterwheel
3. Increase and decrease the field current on the generator, when motor-operated rheostat is applied
4. Indicate the gate position
5. Indicate water level in the forebay.

The control also may be arranged to perform additional operations, as follows:

6. Supervise the generator oil circuit breaker
7. Supervise the annunciator lockout relay
8. Supervise other relays in the station
9. Supervise the voltage regulator, placing it in and out of service when necessary
10. Open and close the feeder breakers, motor-operated disconnecting switches, etc.

Other operations and signals may be obtained depending upon the particular application.

Kentucky Hydro-Electric Company's Kentucky River Dam No. 7

Automatic switching equipment now is being built for the Kentucky River Dam No. 7 plant of the Kentucky Hydro-Electric Company. This equipment involves several unique features in hydro-electric control.

The station contains three 850-kva. 2.2-kv. vertical waterwheel-driven generators. The following are some points in connection with the control of this station:

1. The governor equipment is the full-automatic oil pressure type, equipped with speed-matching devices. The machines are automatically synchronized to the station bus by means of one automatic synchronizing element. This element is arranged for transfer between each of the machines, a speed-matching element being mounted on each governor equipment.
2. The machines are equipped with slow-speed rheostatic type voltage regulators.
3. The station is controlled by audible-type supervisory control from the manually operated Dix River station two miles away.
4. The machines also are under float-switch control. Any machine may be arranged to lead off, and the others start in the desired sequence by means of sequence switches.
5. The units will shut down in sequence on low water level as indicated by the float switch.
6. One outgoing breaker is supplied on the 33-kv. line carrying the total power from the station. This outgoing breaker opens when all the units are shut down. It is arranged for periodic reclosing. In case the breaker opens, the units also will shut down and when it closes again they will start up and synchronize in sequence or re-synchronize.
7. A small commutator is mounted on the speed relay which indicates over supervisory controls whether or not the unit is idling on gate leakage. This commutator gives a tone over the audible supervisory equipment proportional to the speed at which the unit is operating. Therefore the dispatcher can note the machines starting up or shutting down by means of this audible indication.
8. The power plant is built on the crest of the dam. The shaft between the generators and the waterwheel is approximately 20 ft. long. The lower guide bearings, or the one next to the wheel, is of the lignum vitae type. A water-flow indicator is provided on each of these bearings in order to protect against failure of water pressure or flow. This water-flow indicator is equipped with contacts and arranged to operate the annunciator lockout relay.

The various operations under control of the supervisory system are divided into four groups. Three of these groups are associated with the generators themselves and the fourth group is associated with operations common to the entire station. Each of the three groups associated with the three generators is similar in the number and kind of operations controlled and each one is individual to the control and supervision of one generator.

Each of the three generator control groups is arranged for the following operations:

1. Start the generator by supervisory control or release it to full automatic operation as desired. No alarm on this point.
2. Stop the generator by supervisory control or release it to full automatic operation as desired. No alarm on this point.
3. Supervise the generator circuit breaker. Alarm.
4. Supervise annunciator lockout relay.
5. Supervise master automatic relay.
6. Supervise reverse-power relay.
7. Control placing voltage regulator in and out of service and supervise its position.

The fourth group controls operations common to the entire station and is arranged for the following operations:

1. Open and close two motor-operated gang disconnect switches and supervise their position.
2. Open and close the feeder circuit breaker and supervise its position.
3. Supervise the 1-ft. water-level variation in the forebay in ten steps, thereby giving the indication in tenths of a foot.
4. Supervise the 20-ft. flood condition in the forebay in ten steps, thereby giving the indications in 2-ft. units of head.
5. Supervise the position of relay "5X" which is associated with a predetermined low water-level point.

There are many other operations performed by the audible-type supervisory control in the hydro-electric station in addition to those listed above.

The station is fully protected against practically all abnormal electrical and some abnormal mechanical conditions, even though some may manifest themselves very infrequently.

Automatic Hydro Plant Control*

Although completely automatic railway substations have been in service since December, 1914, it was not until October, 1917, that the first automatic hydro-electric generating station was placed in operation. This first station, a low head plant on the Cedar River at Cedar Rapids, Iowa, is owned and operated by the Iowa Railway and Light Company and contains three 500-kw. vertical synchronous generators each provided with full automatic control.

As may be expected automatic operation of this plant was not planned at the time of it inception, but in order to save separate attendance charges and so make the investment more profitable complete remote control over pilot wires from the main steam station, about 3,300 ft. away, was considered at first. This plan was abandoned, however, in the early stages of the design and complete automatic starting and protection features by relays in the station itself substituted instead.

The automatic operation of the station was successful from the beginning and it soon was apparent that there was a large filed for stations of this kind, especially in small power sites which otherwise would be impossible or in any case unprofitable to develop on account of the expense of attendants. With completely automatic operation all shifts of station operators would be eliminated and a single attendant living near the station could attend to all the duties in and about the station including electrical maintenance. In fact, it would be possible for one man to attend to several of these plants if they were conveniently located with respect to each other.

Comparatively small stations of this kind could operate at a fixed load setting and would feed into a large

* Report of subcommittee of hydraulic power committee—H. Bany and W. E. Melarkey.

system so that speed regulation was of secondary consideration. Hence some very simple means of controlling the waterwheel gate could be used, either an electric motor, a so-called servomotor (operated by water pressure in high-head plants), or if desired a standard oil-pressure governor with suitable electrical control for opening and closing the gates. Running at fixed load thus would allow the gate setting to be maintained at a fixed value for certain water or load conditions. Also, since any attempt to regulate the voltage of a small unit in a large system would be superfluous, a fixed value of exciter and generator field excitation could be used at all times thus dispensing with the a.c. voltage regulator.

The method of giving the starting indication could consist of energizing the transmission line feeding the station which then would energize the control bus and provide the necessary control power for the unit to perform the starting sequence. The shutdown indication could be given by opening the tie breaker between the automatic station and the power system so that the generator thus would run at no-load and so after a short time-delay be shut down automatically.

No operating or tripping battery would be required and all devices could obtain their operating power from the a.c. line and from the exciter, and all main circuit devices could operate on the undervoltage relay principle so that in case of power failure their contacts would open.

No elaborate means of synchronizing the machine to the a.c. line would be necessary because the use of the amortisseur winding on these machines would permit them to be connected to the line without field as induction motors at approximately synchronous speed. In the case of synchronous generators, field excitation would be applied at the same instant and the machine would pull itself into step with the building up of the field current and would immediately take its load. Protection necessarily would be provided against all ordinary operating emergencies, to shut down the machine either temporarily or until the necessary attention permitting its restart had been given and to disconnect it from the system to prevent damage to apparatus.

In its basic form this scheme still is used in by far the greater majority of automatic hydro-electric equipments even though the size of the units controlled has been increased from 100 kva. up to about 10,000 kva. However, the sizes of power systems for which these equipments are being furnished also have been increased so that the ratio of the sizes of units controlled to system capacity has not increased exactly in the above proportion.

It soon was found, as would be expected in a new development of this kind, that some minor modifications were necessary or advisable. For example in the early installations the time-delay relays were of the air-bellows type and oil-dash-pot type, little else being available. It was found that temperatures existing in unattended tsations caused unreliable operation, therefore the present design includes fewer timing functions and they all are performed by devices operating on the induction principle. The relay shown in Fig. 1 is typical of the a.c. motor-operated timing relays used in these equipments.

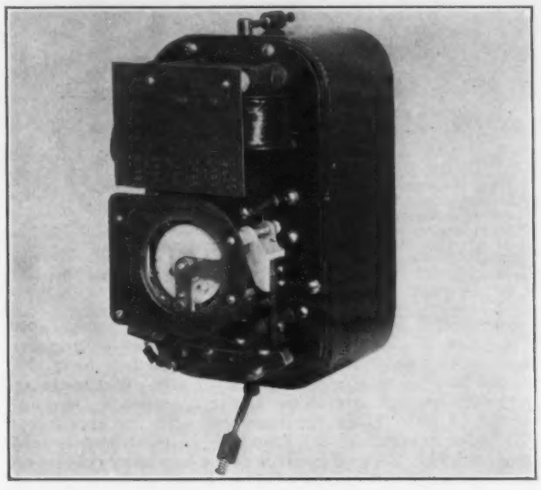


Fig. 1. Motor-operated timing relay, cover removed.

It was found further that the method of giving the stopping indication by de-energizing the line is objectionable in the majority of cases because full load is removed suddenly from the generator resulting in overvoltage conditions and causing excessive potential strains on lightning arresters, insulators and other high-voltage equipment. Hence this method of starting and stopping is used now only when some form of remote or supervisory control is provided so that the load of the generator is reduced gradually before the oil circuit breaker de-energizing the transmission line is opened. A time switch, float switch, supervisory control, or combination of the above usually is found to be the most satisfactory means of giving starting and stopping indications.

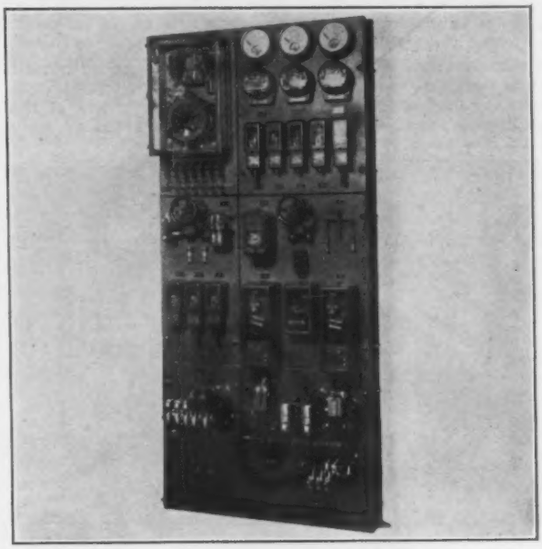


Fig. 2. Automatic switching equipment in Japanese station.

It has proved advantageous, partly due to the increase in size of units controlled, to include a voltage regulator in most equipments. For a similar reason an oil circuit breaker is now used in every case as the electrically operated main circuit device in the a.c. line instead of an oil immersed contactor. Also it soon was found by experience that applying normal value of field excitation in one step instead of two steps as first was contemplated immediately with the closing of the breaker, actually would shorten the time required for the machine to pull into step and so result in smaller system disturbances. Figure 2 is a factory photograph of a typical switchboard for a single-unit automatic station of the latest and simplest design.

The largest full-automatic hydro-electric station using the simple scheme of control described above is the Soft Maple station of the Northern New York Utilities. Figure 3 shows an interior view of that station. The generators are rated 9,375 kva. each.

Figure 4 shows the largest single-unit hydro-electric station with automatic control, the Elwha station of the Washington Pulp & Paper Company at Port Angeles, Wash. Although the control is designed for full-automatic operation the station at present is operating under partial-automatic control due to some manual features still present in the hydraulic equipment.

Induction and Syncronous Generators

Although originally it was felt that the squirrel-cage induction generator would play a large part in automatic hydro-electric stations on account of its greater simplicity it has not lived up to these expectations. The machine itself is more simple and rugged because no source of d.c. excitation is necessary and the control also is somewhat more simple. Still, the fact that the induction generator is dependent upon other synchronous machines for its excitation and that the resulting lagging current makes the system power factor poorer

is a decided disadvantage. Even though direct current for excitation must be provided in a synchronous generator installation this has not been found to be any drawback because direct-connected exciters usually have been used and they have been found to be very reliable. The synchronous generator may be over-excited thus improving the power factor of the system materially and this is the chief advantage that has brought about its universal use.

Figure 5 shows the interior of an early partial-automatic station with an induction generator, operated by the Ontario Power Company at Ontario, Calif.

Gate Operating Mechanisms

As previously mentioned the majority of automatic hydro-electric equipments operate with a fixed gate opening and hence are non-regulating. Since one of the principal functions of the standard oil-pressure gov-

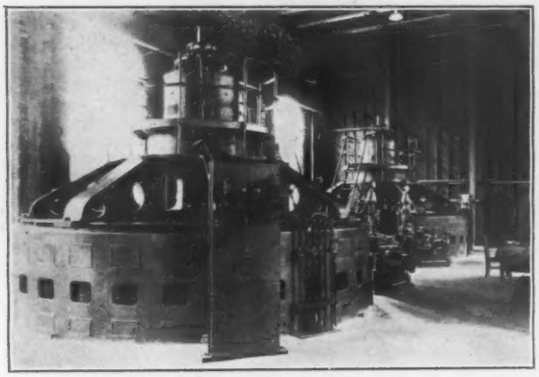


Fig. 3. Soft Maple plant of the Northern New York Utilities, Inc.

ernor is to regulate the load or speed it would seem as if there should be a large field for some simpler and cheaper operating device. Thus far, however, very few governor substitutes have been installed in automatic stations. This may be accounted for to a large extent by the fact that the oil-pressure governor has become a standardized piece of apparatus for manual stations and so can be obtained more readily at the present time than some device which undoubtedly would be simpler in operation, but, from the manufacturers' standpoint be more "special" to build. Also the operating company often has in mind that at some time or under some emergency conditions it may desire to operate a given station regulating, thus making the added cost of the governor worth while.

In general it may be stated that the governor as compared to the usual governor substitute is considerably more flexible in operation and gives some added overspeed protection. In addition, when accurate speed control at no-load is required preparatory to synchronizing it has very decided advantages. No matter what type of gate operating machanism is used, it should have the following characteristics:

Some electrically controlled means of causing the mechanism to open or close the gate must be present. On a governor usually a small solenoid is incorporated which when energized causes the mechanism to open the gates and when de-energized causes it to close them.

Some form of automatic gate-locking device or brake must be provided in the closed position so that if the closing power is removed the gate cannot drift open.

The rate of gate opening preferably should be independent of rate of closing. The former should be separately adjustable to give a very slow rate of opening during the starting sequence and should not vary with external variable conditions, such as ambient temperature. Although an oil dash-pot formerly was used for this time-delay function in the older equipments and in the majority of cases gave very satisfactory service, with the increasingly exacting operation necessary it has been found advisable to discontinue its use and replace it with a later type of time-delay device which does not have erratic time-delay characteristics. When using a governor substitute and in the absence of sufficiently slow rate of opening the gate, an extra limit switch to hold the gate in the synchronous speed (no load) position generally is necessary so that the acceleration at synchronous speed is not too rapid.

The source of operating power, whether oil under pressure or electricity, must be reliable. In the oil-pressure governor extreme reliability is obtained by having the electrical control (starting solenoid) operate on the under-voltage release principle and by incorporating a suitable low-oil-pressure relay which causes the gate to be closed when the oil pressure falls to the minimum operating value. In the case of governor substitutes particular attention must be paid to the reliability of the operating source for in the case of its failure while the station is in operation the unit cannot be shut down.

It should be noted that when the standard governor is operated non-regulating the speed adjustment, by means of a synchonous motor, is raised to the point which will allow the gate to open to its limit-stop setting, within the normal range of system frequency variations.

A very interesting installation operated by the St. Lawrence Valley Power Company and not employing a governor for gate opening is described under the title of "Automatic Non-Governing Hydro Plant" in the June 12, 1926, issue of the Electrical World.

Wheel Characteristics

The wheel characteristics affect the automatic control to some extent. The average reaction turbine will start on a smaller gate opening than is required at synchronous speed (no load) and the required accelerating characteristics of the wheel usually can be obtained by a slow rate of gate opening from the starting or break-away position up until the synchronous speed (no load) position. In certain installations, however, a wheel may require a larger gate opening for starting than for synchronous speed and in this case some means is provided for opening the gate rapidly to the break-away position, then closing it to some lower value and gradually re-opening until the synchronous speed value again is reached. This feature can be obtained quite simply on several types of governors by means of a cam-operated lever arrangement, but it ordinarily requires additional relay equipment if a simple form of governor substitute is used. The object of this particular scheme of operation of course is to have the generator reach synchronous speed quite slowly and so facilitate paralleling with the line.

Protection

As is customary in automatic switching equipments protection against all ordinary operating emergencies should be included. For hydro-electric equipments this protection is as follows:

A.c. undervoltage
A.c. overvoltage
A.c. overcurrent
Excess temperature due to sustained moderate overload

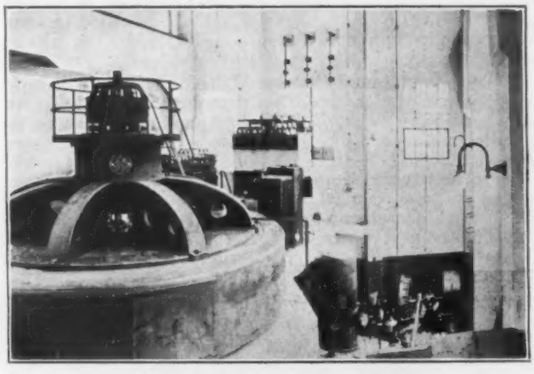


Fig. 4. Automatic switching equipment, Glines Canyon plant, Washington Pulp & Paper Company.

Excess temperature due to single-phase operation
Excess bearing temperature
Loss of generator field
Exciter overvoltage
Low governor oil pressure (for oil-pressure governors)
Machine overspeed
Insulation failure of machine windings (for larger machines).

Automatic Synchronizing

For special applications where the type of generator or the size of a.c. system will not permit connecting the machine to the line without field there has been developed the automatic speed control and synchronizing equipment which simulate the conventional manual scheme of paralleling the machine with the line.

In order to regulate the speed of the generator before synchronizing, a speed-control relay has been developed which generally consists of two small motors geared together in such a manner that when one is driven from the line and the other from the generator either one or

the other of two contact circuits will be made depending upon whether the machine is running fast or slow. A circuit to the governor synchronizing motor thus is controlled to bring the machine frequency approximately equal to that of the system. At a sufficiently small difference in frequency and phase-angle the synchronizing relay operates to close the breaker. In order

Fig. 5. Remote-controlled 500-kva. hydro plant of Ontario Power Company, Ontario, Calif.

to load the generator after it is connected to the bus a circuit is made for the synchronizing motor to raise the governor speed adjustment. An adjustable limit switch on the governor itself then operates to open this circuit at the desired speed setting.

Figure 6 shows a view of the speed control relay and Fig. 7 a view of the synchronizing relay, both with the cover removed.

Although automatic synchronizing is perfectly practical and may be the only type that can be used for certain special installations it must be expected that it is somewhat slower than the ordinary rapid and positive method of connecting the machine to the line at synchronous speed without field. The speed of its operation is comparable to that of manual synchronizing, but may actually be somewhat slower.

Low Reactance Machines Without Amortisseur Windings

Occasionally it is found advantageous to make automatic an existing old installation which contains gen-

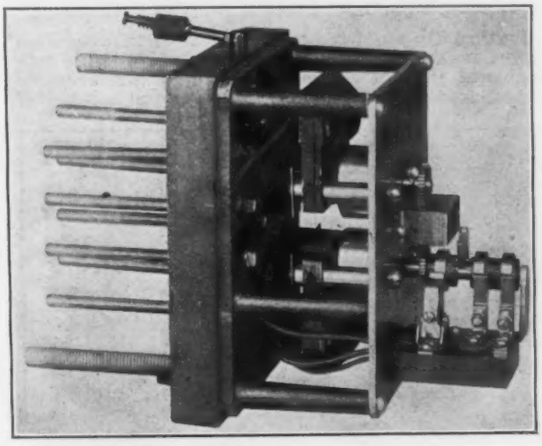


Fig. 6. Speed indicating relay, cover removed.

erators without amottisseur windings. Since the 95-per-cent-speed (without field) synchronizing method offers the important advantage of being the most rapid and positive means of synchronizing thus far available, it would be desirable to employ it even in installations of this type. This has been done in some instances. It is not always certain that the synchronizing torque of these generators is sufficient to pull them into step in all cases when connected to the line without field in this manner. Hence it is advisable when considering an application of this kind to make preliminary tests to be certain that it will be satisfactory from the standpoint of machine and system. It has been necessary in some cases to add a step of reactance permanently in circuits with machines of very low reactance so that the magnetizing inrush is not too severe.

Exciter and Voltage Regulators

In order to obtain the most reliable source of d.c. excitation for synchronous generators a direct-connected exciter generally is furnished for each unit controlled. Parallel operation of exciters, whether direct-connected or driven by a separate machine, should not be attempted on account of difficulties in obtaining proper division of current through the entire range of generator load. In fact, the parallel operation of d.c. machines is one of the most difficult problems encountered in automatic station control and is to be avoided wherever possible. The temporary exchange of some wattless current on the generators until both exciters have reached the same operating temperature is not a very serious matter, but the parallel operation of a hot and cold exciter with the same field rheostat setting usually is out of the question except with special regulating equipment.

The most desirable operation is obtained with one regulator for each direct-connected exciter. Although there are in operation automatic stations employing one common regulator for several exciters, and even stations with a common exciter and regulator for several a.c. generators, added complications are necessary to insure an operative equipment and so are avoided wherever possible.

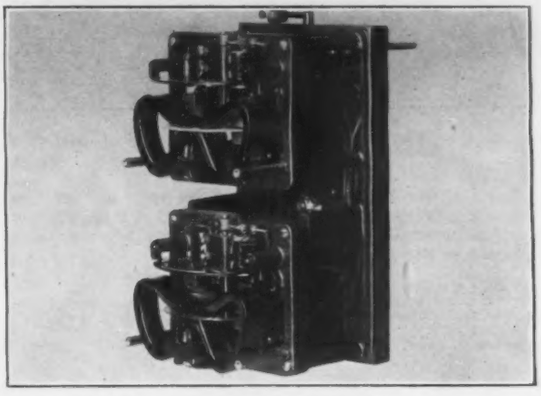


Fig. 7. Automatic synchronizing relay, cover removed.

Automatically Operated Brakes

The use of automatically operated brakes to any extent has been a rather recent development in automatic hydro-electric stations. In many installations it is impossible to bring the units to rest without the use of brakes because of gate leakage, especially after the parts have become worn. Although the manufacturers of bearings actually maintain that bearing failure while running at these abnormally low speeds is very unlikely to occur, in case of overheated bearings while running at normal speed it would be impossible to bring the unit to rest and so prevent further damage even though the bearing temperature relays and control functioned properly. This feature, of course, becomes all the more important with the increase in size of machines which has taken place within the past few years.

Proper interlocking is provided when these brakes are used so that the gate must be completely closed and the oil circuit breaker open before they can be applied. Also in order to reduce unnecessary wear of the shoes some time-delay should be introduced before their application to give the wheel an opportunity to decelerate to its steady running speed. This time-delay usually can be obtained by means of a throttling valve and receiver in the brake application line, but also may be obtained by the addition of a separate time-delay relay for the purpose.

Compressed air offers the greatest advantages as a braking medium and since a source of compressed air is present in a well equipped station for cleaning purposes compressor equipment usually should result in no added investment. A fluid medium such as oil or water is practically incompressible and does not result in such smooth braking qualities as air. Also, any leakage of air does not have the same objectionable features as

leakage of oil or water. The governor oil-pressure system ordinarily should not be resorted to for obtaining air or oil for brakes on account of the possible reduction in reliability of the supply to the governor. In sufficiently high-head plants penstock pressure may be used to advantage for the brakes.

Supervisory Control in Hydro-Electric Station

In any power system comprised of several generating units grouped under the supervision of a load dispatcher it is necessary that this dispatcher have proper means of supervision of each of the units under his control. With manual stations this supervision is supplied by a telephone system linking the stations with the dispatcher, but in the case of automatic stations, when these form an important percentage of the system capacity, some other means must be found.

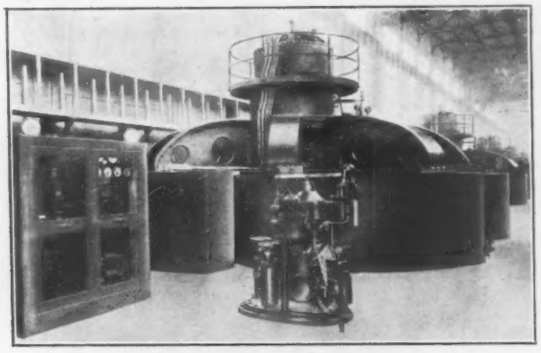


Fig. 8. Automatic equipment in Shipping Port plant, Louisville Hydro-Electric Company, Louisville, Ky.

This means has been provided by any one of the "supervisory systems" now on the market which allow a central operator or load dispatcher at a remote point to perform the following functions:

Control starting and stopping the machines,
Transfer starting and stopping control to and from master element in station (such as float switch, time switch, etc.),
Control load,
Control voltage;

And to receive indications as follows:

Position of the machine control,
Wheel gate position,
Water level,
Open and closed position of brakers.

Also by means of a "telemetering system" it is possible to transmit readings of meters to the load dispatcher's office, using in some cases the same wires for both the supervisory and the telemetering systems.

It should be understood that supervisory control is merely to be superimposed upon the automatic protective features and such being the case it performs only a permissive function in allowing the desired operation to take place when proper conditions exist for the operation. However, it allows an expert operator's judgment to be used in system emergencies or under abnormal conditions to perform operations which may be impracticable to obtain with relay settings, especially if several stations are involved.

A very unique partial-automatic switching equipment employing the cable type of supervisory control for eight 12,550-kva. vertical shaft generators and two transformer banks in one station will be placed in operation soon by the Louisville Hydro-Electric Company. It is the largest hydro-electric station with automatic control thus far installed and the electrical layout in it is a complete departure from the conventional design.

The usual central switchboard has been eliminated entirely and has been replaced by individual control panels installed in cabinets or cubicles alongside of each generator. Each cubicle, which is a sheet-steel container with double glass doors both front and back, contains the relay equipment for the automatic control and protection for its generator. Figure 8 shows one of these cubicles installed in the station together with the generator it controls and the hydraulic governor.

The control keys and meters for the eight generators and two transformers are assembled in a small control cabinet 6½ x 3½ x 1 ft. on the desk of the attendant in charge. This cabinet is shown in Fig. 9.

When the attendant desires to start a unit he operates the starting key which places the control in readiness for this operation and which indicates by means of a signal light on the generator cubicle that the unit is ready to be started. The floor attendant then immediately operates the starting button on the cubicle, the waterwheel governor gradually opens the gates to start the wheel and the generator comes up to speed. When the electrical conditions are correct the machine is synchronized automatically and the attendant in charge then loads up the machine to the desired amount.

The advantages of this arrangement in a station of such large capacity are a saving in floor space, a saving in station wiring and the centralizing of the control at one small controlling cabinet consisting of one 3½-in. panel per unit controlled instead of being distributed over the conventional type of switchboard with a larger number of 24-in. panels.

Load Control

To control the flow of a stream or to obtain the most economical values of load with a varying stream flow several simple schemes of regulating the load of a machine in accordance with the water level have been developed.

The most direct method uses one Seslyn motor (the receiver) with its rotor directly connected to the load-limit stop of the standard oil-pressure governor, and a second motor (or transmitter) with its rotor directly connected to the float in the forebay. These two motors are fundamentally two synchronous motors connected in parallel so that a certain movement of the rotor of the transmitter causes a corresponding movement of the rotor of the receiver on the governor. Hence any change in water conditions causes an immediate readjustment of the governor setting.

The second, but less expensive method, employs two rheostats for the purpose, one direct connected to the waterwheel gate and another to the float. By means of a balance relay whose coils are connected in circuit with these rheostats the proper control circuits are made so that the gate position is changed in steps according to float position. This scheme also is applicable to the ordinary type of governor substitute as well as to the oil-pressure governor.

Partial-Automatic Stations

Particularly when the converting of certain older installations from manual to automatic operation is contemplated there is considerable field for the so-called partial-automatic equipment. The general scheme of

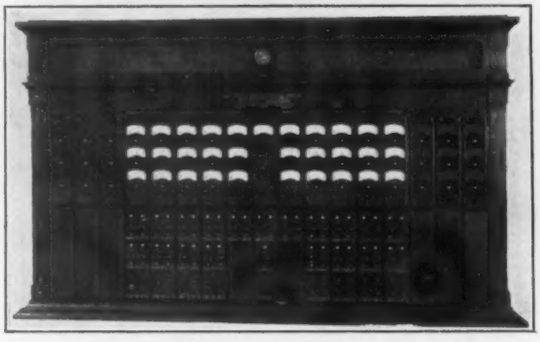


Fig. 9. Dispatcher's control cabinet in station shown in Fig. 8.

operation for this type of equipment is to include all the protection usually afforded a completely automatic station, but to omit all automatic starting and synchronizing features leaving these latter functions to be performed by an attendant.

In older installations the expense of providing all manually operated devices with completely automatic control usually involves considerably more expenditure of money than merely providing automatic, or emergency shutdown features. In fact, the more important devices such as the oil circuit breaker and governor may be equipped already with these emergency features and the expense of any extensive additional changes may be

unwarranted. Also, partial-automatic equipments are suitable particularly for such older installations in which the generators may not be satisfactory for connecting to the line without field, as an alternative to furnishing the automatic synchronizing equipment.

In any case, for partial-automatic stations which incorporate just those automatic starting or protection features desired. it is understood that the necessary manual supervision must be supplied for the automatic features that are not included.

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Automatic and Semi-Automatic Hydro Plants on the San Joaquin Light & Power Corporation's System

By C. P. Rhine*

The two induction generator plants which are included in this report were placed in operation early in 1919 and the results have been so gratifying that there is no question that a considerable output in kilowatt-hours has been made available at small expense. These two plants have been running continuously when water is available without any operating difficulties in the machinery or electrical apparatus.

Power House No. 1-A

Power House 1-A is built on the flow line to No. 1 power house forebay reservoir and at the point where the water empties into the reservoir. The contour of the ground at that point is such that the lower end of the flow line is at an elevation of about 45 ft. above the water in the forebay. Originally the water was carried in a steel pipe down the hill to the reservoir and allowed to run into it without any use being made of the fall, the pipe not being under head, but being used simply as a flow line. For the new plant, a 60-in. wood-stave pressure pipe was laid by the side of the steel pipe and the water now passes through it and is carried into the automatic power house which discharges directly into the reservoir. The wood-stave pipe is carried on concrete saddles about 8 ft. apart and follows the contour of the ground, which makes it an inverted siphon. A drain valve was installed at the low point on the pipe and an air valve at the point where the pipe enters the power house. No standpipe was provided at the intake because the water to the pipe is controlled by a radial gate in the flume some 20 ft. above the end of the pipe. An automatic bypass was provided around the pressure pipe by the construction of a weir over which the water rises and spills when the plant shuts down. The weir spills into the old pipe line, which was left in position. The bypass is necessary at this plant because the No. 1 power house is a station of large output and nothing can be allowed to interfere with its water supply. The No. 1-A generator is a 425-kva., 6.6-kv., 245-r.p.m. induction machine driven by a 600-hp., 39-ft. head, end-inlet, double-discharge Francis-type turbine. Power is transmitted at the generator voltage a distance of about 4,400 ft. to power house No. 1, where it is stepped down to 2.3 kv. and connected to the main busbars of this plant.

As no waterwheel governor has been provided, the gates of the turbine are operated by a 1-hp., 220-volt,

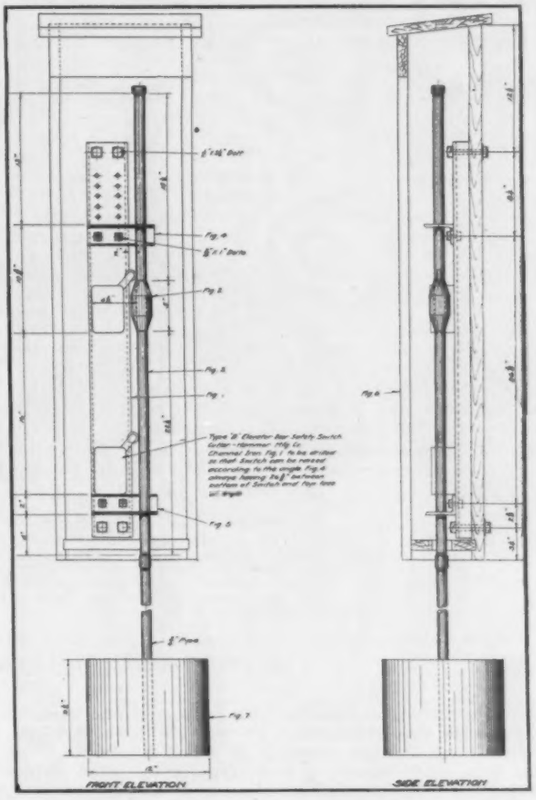

Fig. 1. Assembly of float switch for No. 1-A power house.

three-phase induction motor the direction of rotation of which can be regulated by the closing of the proper contactor on the control panel. The control of the turbine gates can be given to a pull-button switch for hand operation by closing the triple-pole, double-throw switch on the control panel to the proper position. The other throw on this switch gives the gate control to a float for automatic operation. The float is at the intake to the pipe line and is set to close one pair of contacts when the water begins to spill over the weir, and to close another set when the water is drawn down to a distance of 9 in. below the crest of the weir. In the first case the turbine gates are open until the water starts to fall and the float switch contacts open, and in the other case the gates are closed until the water starts to rise again. The motor is geared down so that the gates work quite slowly and in that way the travel is not far before the float switch opens owing to change of level of the water at the intake. In fact, the regulation is so close that about 45 min. is taken for the water to be drawn down from the spilling point to the lower limit of the float's travel, and about the same time is taken for the reverse operation.

With this float arrangement the maximum possible output is obtained from the water flowing in the ditch. Two signal lamps on the board indicate high and low water respectively. When the float is intermediate between the contacts neither lamp is burning. In "putting the plant on the line" the attendant brings the unit to the proper speed by using the pull-button control on the gates. He then closes the oil breaker and, still with the control button, brings the load up until neither signal lamp is burning. He then throws the double-throw switch to the float-control position.

In case the power line is de-energized from power house No. 1 the low-voltage release on the oil breaker disconnects the plant from the line thus preventing load being thrown back onto the semi-automatic plant

* Report of subcommittee of hydraulic power committee.

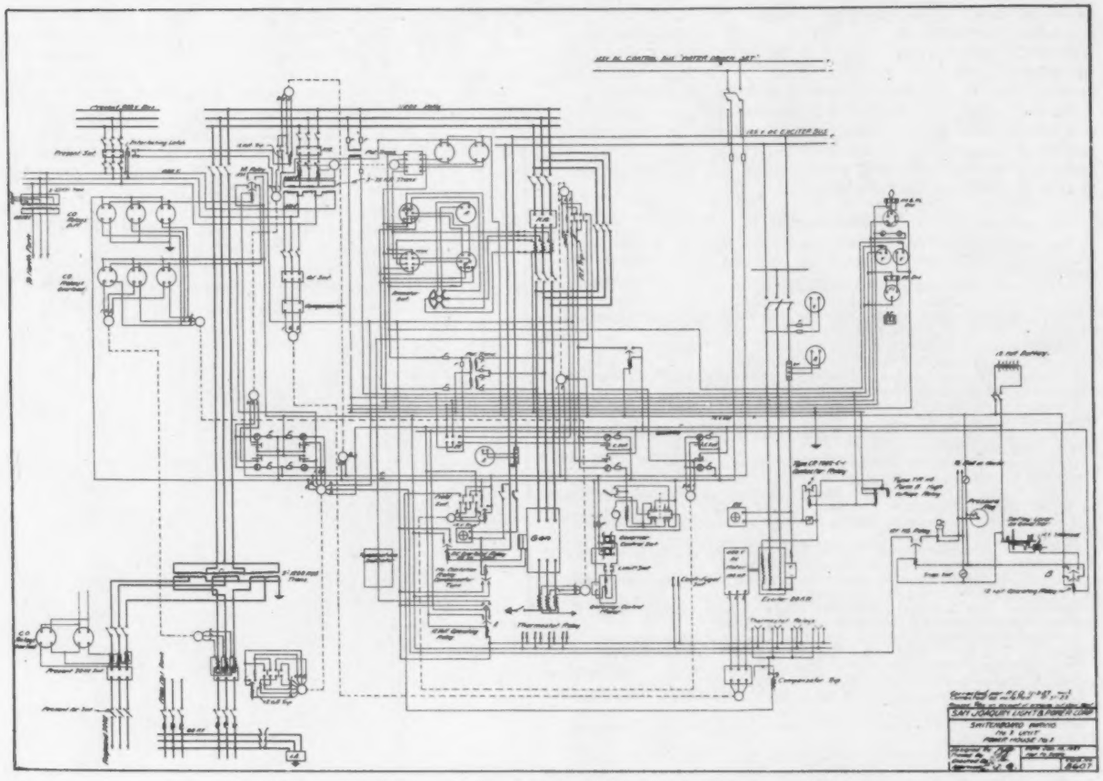

Fig. 1-A. Switchboard wiring for automatic control at No. 3 power house.

with the induction machine still connected and running at a high rate of speed. To provide for overspeed, either from the line opening at power house No. 1 or for any other reason, a centrifugally operated switch is provided on the shaft to close a set of contacts that in turn operates the gate motor in a direction to shut down the unit. An overload relay with circuit-opening hand-reset contacts is used as an interlock so that when the motor is closing down for overspeed the float cannot operate it to open up, as would be the case if immediately the water began to rise at the intake. Three reverse-power relays have been installed and connected to open the generator oil switch by means of a no-voltage release in case of failure of the water supply causing a reversal of power.

While an induction generator cannot run away if it is connected with synchronous machines whose speed is normal it may happen that a short-circuit occurs or line voltage is otherwise reduced to such an extent that the induction generator receives no excitation, in which case it will run away. Since the unit is designed for full run-away speed no damage could be done from this cause, but it would be difficult to get synchronous plants back on the line again without damaging the induction machines because full voltage would be impressed on the induction generators while they were running much above normal speed. No provision has been made for automatic starting because an attendant is kept at the reservoir at all times and he can start up the plant when necessary without interfering in any way with his other duties.

The gate control motor is operated by power taken directly from the line. No auxiliary source of power has been provided because the short distance from power house No. 1 makes the chances of interruption few. On account of the low speed of the unit no protection so far has been installed against hot bearings.

The Crane Valley power house contains a 1,000-kva., 2.3-kv., 458-r.p.m. induction generator coupled to a 1,310-hp., 100-ft. head, single-discharge, overhung Francis-type turbine. This plant takes its water directly from Crane Valley storage reservoir through a 48-in. steel penstock to the turbine which discharges directly into the conduit for No. 3 power house. Provision is made to bypass the water around the plant, but the operation is not automatic in this case, the attendant having to close the butterfly valve to the turbine and open bypass valves from the pipe. An overspeed device for shutting down the machine was considered necessary because the induction plant might be left on the transmission line with only one or two small synchronous plants and with very little, if any, load during switching or trouble. Unless the water were turned off the waterwheels would generate considerably more power than necessary for running the synchronous plants as motors at normal speed, provided the gates were wide open. As a result the whole district would be subjected to overspeed. Therefore, it is considered a good plan to have the induction plant taken off the line and the wheel closed down, thus making it possible for the synchronous plants to get back in step with the remainder of the system and the induction generator plant to be placed on the line later by the attendant.

From the wiring diagram it may be seen that the turbine gates are operated by a small d.c. motor driven by a d.c. generator which is belted to the shaft. No operation of the gates is provided for except to close down the unit when it goes off the line in trouble or when the power on the line fails. The centrifugally operated switch on the generator shaft responds to about 35 per cent overspeed, opening the no-voltage coil on the generator oil switch and also operating the automatic controller on the gate motor. The motor continues to run until the limit switch on the gates opens in the closed position.

Thermo-relays are installed on the bearings and connected to open a no-voltage release on the oil switch thus disconnecting the unit from the line in case of a hot bearing. The momentum of the unit is always sufficient to drive the d.c. generator long enough for complete operation of the gates. In fact, the gates never close tightly enough to stop the machine entirely. Load changes on this plant are made on an average possibly twice a day by the caretaker of the dam and reservoir.

Power House No. 3

Power house No. 3 is in the Crane Valley system of hydro plants, about four miles below Crane Valley dam. As it operates on block loads, automatic floats and load changing devices have not been provided. However, automatic control for closing down the unit has been installed.

Hydraulic Equipment—Penstock is 3,146 ft. long, diameter varies from 60 in. to 48 in.; plate thickness 3/16 to ½ in. Approximately 100 ft. above the Francis type watewheel a flow meter is installed in the penstock. It is connected to an indicating, recording and registering meter by means of two ½-in. pipes.

Watewheels—The original plant contained two single-overhung impulse waterwheels driving two 1,000-kva., 500-volt generators. When the conduit was enlarged to carry 170 sec.ft. it was deemed advisable to install a large reaction waterwheel having higher efficiency than the old type impulse wheels. Automatic features were incorporated in order to reduce the operating force to one man. The new waterwheel is a horizontal Francis type turbine with cast steel spiral flume, single discharge, 6,000 hp., 374-ft. head, 170 sec.ft., 450 r.p.m., with bronze runner and cast steel gates. Governor is an oil pressure relay valve type with a capacity of 20,000 ft. lb. It is self-contained with a belt-driven oil pump and necessary oil pressure tanks. Relief valve is 16-in. with a cast steel body. It may be operated either synchronous or water-wasting. A 48-in. hand-operated butterfly valve is installed as a shut-off valve for the turbine.

The generator is rated 11 kv., three-phase, 60-cycle, 3,750 kva., 450 r.p.m., horizontal type with neutrals brought out for differential protection. One exciter is provided for the unit; 125-volt, 80-kw., 800 r.p.m., direct-connected to a 75-hp., 440-volt, three-phase induction motor. Switchboard for new unit consists of two vertical panels and a swinging bracket.

Automatic Features—The intention is to provide such automatic devices as will protect the equipment against damage which might result from defects in the transmission line or the station apparatus. No provision is made for automatically starting up the machine or making load changes.

The main features covered by the protection devices are: overspeed and runaway, transmission line troubles, high voltage, loss of excitation, short inside of generator, hot bearings, low pressure in governor oil pressure tank, short in generator field, and governor belt failure. By referring to the wiring plan the methods of obtaining the desired automatic protection may readily be followed.

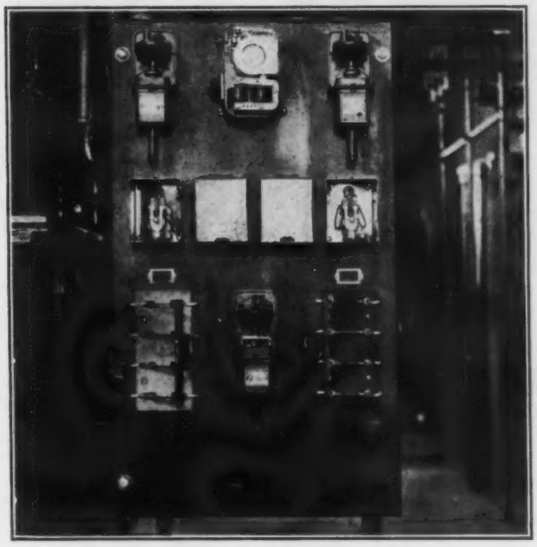

Fig. 2. Load control relays.

Overspeed and Runaway—When the generator speed is about 20 per cent above normal the contacts of a centrifugal switch mounted on the generator shaft close, thereby operating relays A and B which trip the generator oil circuit breaker, give an alarm in the power plant and operators' quarters, and also close down the waterwheel by tripping the safety lever on the governor.

Transmission Line Troubles—Overload relays trip line switch.

High Voltage—To prevent bus voltage rising more than 10 per cent a high-voltage relay in connection with a contactor relay which normally shunts out an extraneous resistance operates to cut in this resistance to hold voltage near normal.

Loss of excitation will close the contacts of a no-excitation compensator-type relay which operates relays A and B, thereby closing down the unit and tripping generator and field switches.

Short Inside of Generator—Differentially-connected relay protections are provided between high-voltage circuit breaker and generator neutrals. The operation of these relays will trip all circuit breakers and close down the unit.

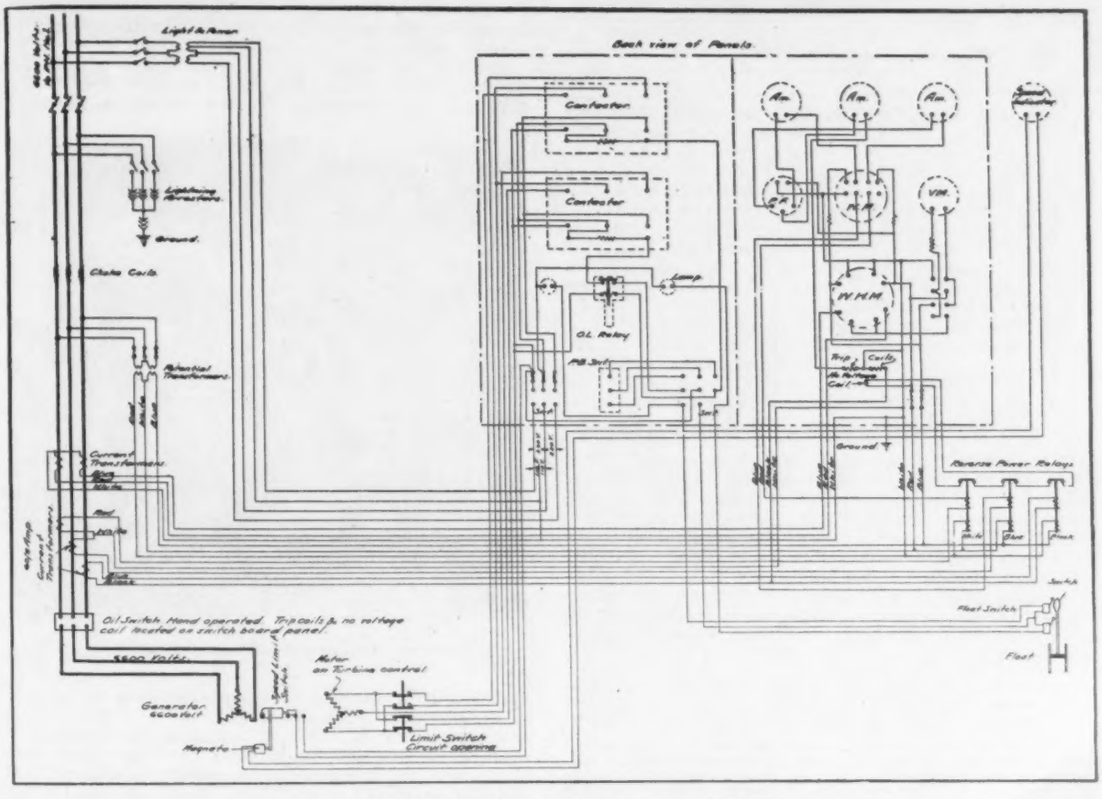

Fig. 3. Wiring plan for No. 1-A power house.

Hot Bearings—Thermostat relays installed in the bearings of the main unit and the exciter, when operated, will close down the unit and trip the generator and field breakers. Operation of the relays on the exciter bearings also will trip the motor compensator.

Low Pressure in Governor Oil Tank—This causes pressure regulator to operate sounding an alarm in the power house and operators' quarters.

Short in generator field will impose an overload on a 300-amp. relay which will operate relays A and B and thereby close down the unit.

Governor Belt Failure—This trips safety lever on governor and closes down the unit.

Power House No. 2

Power house No. 2 is located about four miles below No. 3 and is a synchronous generator plant once having several operators, but now being operated successfully

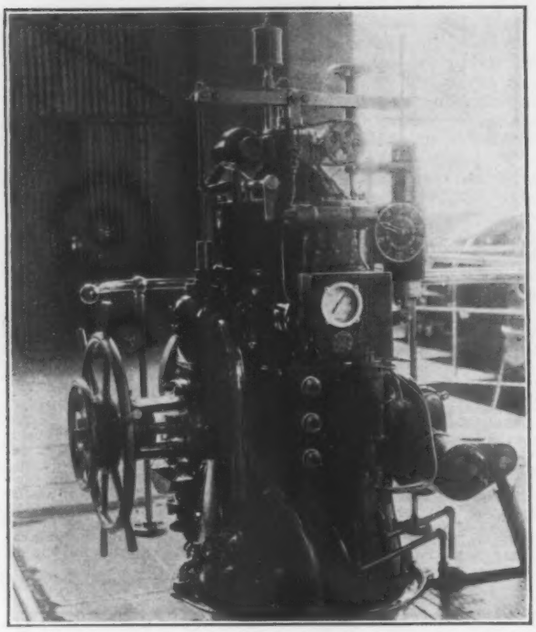

Fig. 4. Oil-pressure actuator with load-control mechanism attached.

by one man since the automatic equipment has been installed. The automatic equipment is the same as for No. 3 power house with one added feature, a float control which will be described. The waterwheel is a Francis type 5,250-hp., 275-ft. head, 450 r.p.m., double discharge, with oil-pressure governor, belt-driven oil pump and synchronous-operated relief valve. The generator is 2.3-kv., 60-cycle, three-phase, 3,000-kva. horizontal, waterwheel type; exciter 125-volt, 50-kw., 900-r.p.m., driven by a 100-hp. Francis-type waterwheel and a 75-hp., 2.3-kv. induction motor.

Load Control—Because of the large forebay for No. 2 power house the methods used at No. 1-A or Mount King power house would not be satisfactory as the control motor would operate so many times before the water could draw down or rise enough to break contact that the governor would greatly over-travel one way of the other. Therefore the method shown in the accompanying diagram was devised to give greater time intervals than was possible with any thermal device. Relays L, H, I and D are of the standard plunger-type, all of the current-operated type, 3-amp. rating. All except D are of the instantaneous type, relay I having a third contact and flexible connection to the plunger contact. D is of the definite time-delay type. The long-time-delay relay also is standard although not in extensive use owing to the rather special nature of its applications. The explanation of this method of operation follows:

Consider that the high-water contacts close. This puts alternating current on relays H and D. Relay H picks up instantly putting direct current on the governor-control motor through contact A to pick up some load.

Obviously the motor must not operate too long or too much load would be picked up. Relay D in the meantime is closing its contacts in a definite time of 2 or 3 sec., or whatever is found to be the proper interval. Immediately on closing its contacts relay I is energized and picks up instantly. On closing its contacts, three things are accomplished simultaneously: (1) Energy is maintained on I through contact B and flexible connection entirely independent of relay D, and holds in; (2) Relay D is shunted out and opens, taking its normal position; (3) The long-time-delay relay starts owing to the action of the synchronous motor which is energized through contact B. Contact A opens at once and stops the governor-control motor; all this within 2 or 3 sec. after the float first contacts.

Motor M continues to operate moving arm A around through 180 deg. in a definite time of 5 to 25 min., depending upon what may be found necessary to allow the forebay to draw down. At the end of this interval, contact B is opened by lever A and, provided the high-water contact has broken in the meantime, motor M stops and the lever A resets. Also relay I is de-energized, taking its normal position and breaking the shunt around relay O. If, however, not enough load has been picked up and the high-water contact still is maintained the governor control motor will start immediately when contact A recloses and relay D, receiving energy immediately on having its shunt broken, begins to time the operation as before. The operation for low-water contact is just the same except that relay L is operated instead of H to reverse the governor-control motor and reject load.

Tule Power House

General Considerations—On power systems there often exist moderately sized stream-flow hydro plants whose outputs singly are a small percentage of the system capacity and whose yearly load facaor may be quite low resulting in relatively high kw.-hr. costs. Where such plants have little or no storage and are not called on to govern any part of the system they might well operate self-controlled.

By applying float load control to such plants as well as numerous relays and devices for protection against a number of things that might happen, the operating personnel may be cut down to a minimum. This minimum depends of course upon the amount of plant maintenance and other outside work around the property.

Such plants naturally require occasional plainstaking adjustments in order that the operation may proceed successfully. To that end it is wise that the men retained be those who are entirely "sold" on the scheme of operation and familiar with the equipment. It may be necessary and even advisable to pay these men more as the net saving usually is great enough to justify so doing.

Usually it is possible to transfer the men laid off at plants changed over, so that they are not necessarily let out of work. Operators should not resent the intrusion of the automatic control into their field, but rather welcome the opportunity of studying such operation.

Former Experiences—The San Joaquin Light & Power Corporation of Fresno, Calif., which had been operating five of its smaller hydro plants semi-automatically for several years, in 1927 changed its Tule River power house over to operate as a self-controlled plant. This company has gone into the semi-automatic operation by degrees, commencing with two induction generator

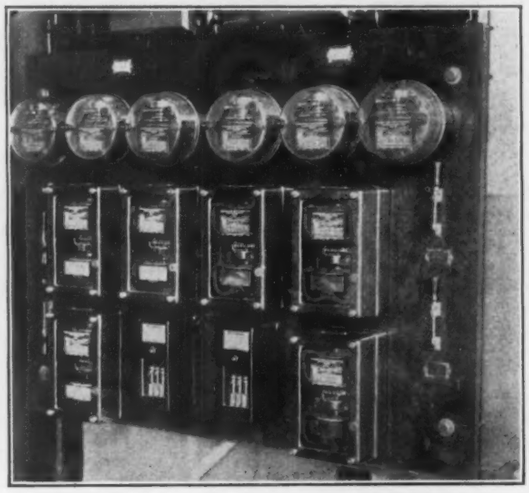

Fig. 5. Generator and bus protection relays.

plants under 1,000 kva. each and extending the practice to synchronous generator plants up to 4,000 kva. at heads up to 400 ft. Gaining confidence with successive ventures it was decided to work the Tule plant over. This plant first was put into operation in January, 1914, and had in its 13 years of operation averaged a low yearly load factor.

This resulted in a rather high kw.-hr. cost and the most feasible way of reducing this cost lay in reducing operating expenses. This best could be accomplished by changing the plant over to semi-automatic operation so that it would require only minimum attendance.

Description of the Project—The Tule River plant is on the Middle Fork of the Tule River in Tulare County, Calif., using water at the present time from the North Branch commonly known as the Doyle Branch. The elevation at the intake is 4,020 ft. whence the water flows through a concrete lined ditch, 26 tunnels connected by concrete box flumes, and one section of wood-stave pipe. At the lower end of the conduit at El. 3,982 the water enters a circular, reinforced concrete surge chamber, 30 ft. in diameter and 20 ft. deep, from which it is admitted into the penstock through gate valves that

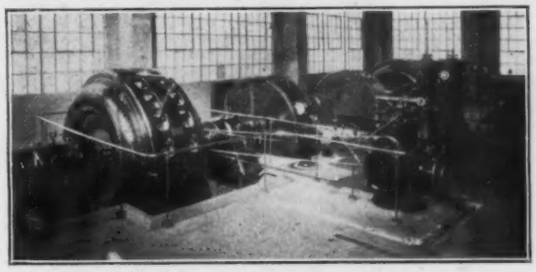

Fig. 6. Generators at Tule power house.

are equipped for motor operation by remote control.

The single penstock is about 3,600 ft. long and varies from 36-in. diameter at the upper end to 30-in. diameter at the plant. The thickness of the pipe varies from ¼ to ⅜ in. The entire pentsock is of the German lap-welded type. The elevation of the center line of pipe at the surge chamber is 3,980 ft., and at the power house is 2,457 ft., giving a total head of 1,523 ft., not counting the small amount of water over the pipe in the surge chamber. There are no branches in the line until it has passed through the power house wall where it enters a Y, each branch of which is controlled by a hydraulically operated gate valve. Each branch delivers water to the single overhung wheel of each of the two units.

Power House.—The power house is a reinforced concrete and steel structure which measures 65 ft. 4 in in length by 40 ft. 6 in. in width and 33 ft. to the eaves. The station contains two units placed wheel to wheel, each operated by a sinble rotor. The pipe line enters at the center of the back of the building and on each side of it, on the ground floor, are two transformers. The switching apparatus is in a balcony above the transformers.

Hydraulic Equipment.—Each unit is operated by a single overhung impulse wheel which is supplied through a needle nozzle of 5⅞-in. bore operating in connection with a relief valve in the main pressure line. Each wheel carries 19 buckets, is 71 in. in diameter on the pitch line, and is rated at 5,000 hp.

Generators.—The two generators are identical in design and rated 3,000-kva., 2.3-kv., 3-phase, 60-cycle, 425 r.p.m.

Exciters.—A 120-kw., 120-volt, 1,000-amp. exciter with sufficient capacity to furish current for both main units is mounted on each generator shaft.

Transformers.—The entire output of the plant is stepped up to line voltage by a single bank of three 1-phase, 2,300/40,000/69,000 Y 2,000-kva. transformers. The station is provided with one spare transformer to be used if accident occurs in any of the bank. As the waters of the Tule are highly mineralized and probably would clog up small circulating pipes the transformer cooling is accomplished by circulating the oil instead of circulating water as is the usual practice.

Wiring.—The line outlets are through wall bushings in the roof. The line from the power house runs down the canyon and out across the valley to Strathmore where the company has a switching station to tie the power house in on the East Side line. The power house is equipped with 60-kv. electrolytic lightning arresters.

Practical Considerations.—The chief considerations in changing such a plant over to semi-automatic operation are those of safety and reliability. Provision should be made for automatic protection and warning against most probable troubles. Protection against extreme overspeed and incidental high voltage probably are the most outstanding requirements to be met with in dealing with synchronous units. Protection against high penstock pressures equally is important although not a new or unusual problem in high-head plants. In connection with the reliable every-day operation of a self-controlled plant the regulation of the load to meet the water conditions is quite the most useful feature if not the most important.

Independent Power Reserve.—In order that a positive operating power would be available and independent of the operating buses to shut the unit down

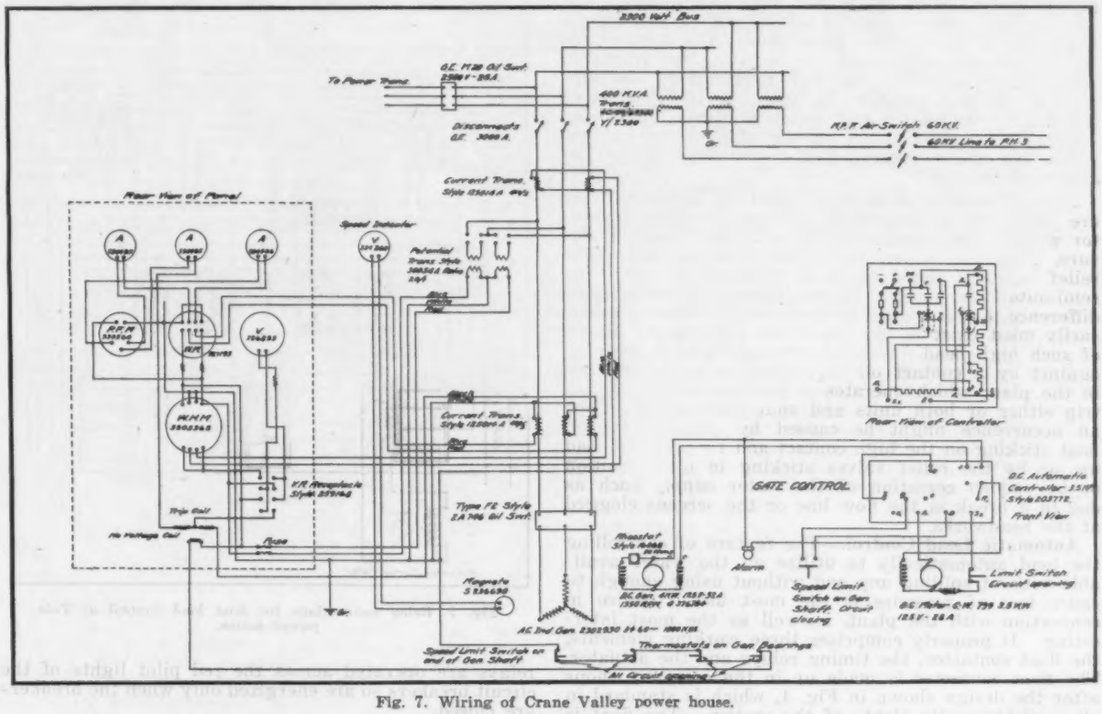
2300 Volt Bus
To Power Trans.
G.E. 1130 Oil Swit.
2300 V - 200 A.
400 K.V.A. Trans.
Y/Y 2300
Disconnects G.E. 3000 A.
K.P.P. Air Switch 60 K.V.
60 KV Line to P.H. 3
Current Trans. Style 136614 A 400/5
Rear View of Panel
Speed Indicator
Potential Trans. 2400/2400 A Ratio 1/1
Current Trans. Style 132046 A 100/5
Type FE Style 2A 706 Oil Swit.
Magneto S 256638
Rear View of Controller
GATE CONTROL
D.C. Automatic Controller 3.5 H.P. Style 803772
Front View
Alarm
Speed Limit Switch on Gen. Shaft. Circuit closing
Limit Switch Circuit opening
D.C. Motor G.E. 799 3.5 H.P. 125 V - 28 A
Thermostats on Gen. Bearings
Speed Limit Switch on end of Gen. Shaft
Air Circuit opening

Fig. 7. Wiring of Crane Valley power house.

whenever necessary the governor oil pressure system was utilized (which is self-contained in the governors) and belted to the main generator shaft. Solenoid-operated oil valves and cylinders were ordered from the governor manufacturer and installed. Standard centrifugal overspeed devices were fastened to one end of the main shafts. These act at 10 per cent overspeed to close a circuit energizing the solenoid valves which in turn admit oil to the cylinders whose pistons operate to lift the regulating valve stems of the governors. This action causes admission of oil to the main operating cylinder causing the main needle to close. An operating pressure of 180 lb. is maintained on the oil system and a variation of 20 lb. either way causes an alarm to sound. Above 10 per cent over-

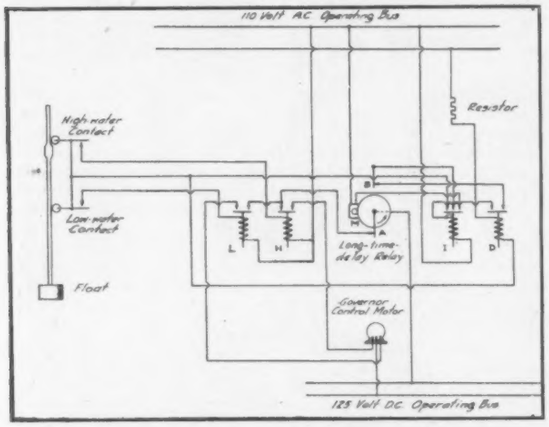

Fig. 8. Diagram of connections for governor control where there is water storage at the plant.

speed, in case the trip devices ever fail to work, there is a mechanical connection between the fly ball stem and the regulating valve stem which comes into action and prevents the speed from going much above 10 per cent. It has been found that 10 per cent overspeed gives a satisfactory margin for speed variations during system disturbances, and without tripping the circuit unnecessarily.

High Voltage.—To prevent bus voltage rising more than 10 per cent a standard high-votage cut-out relay is provided in connection with a contactor for each exciter which normally shunts out an extraneous resistance in the exciter shunt field. The voltage relay is automatically reset, so requires no attention. These same resistances are cut in circuit by the tripping of the field breakers incidental to the generators tripping off the bus for any reason whatever. This was done to prevent excessive voltage rise on the exciters which are direct connected and therefore subject to abnormal speeds.

High Pressure.—Excessive penstock pressure rises are prevented by the relief valve or pressure regulator which opens synchronously with the governor closure, requiring 5 sec. from full gate opening. The relief valve is timed to close in about 15 sec. The semi-automatic nature of the plant has made little difference in this regard as such safety features necessarily must exist in any plant and particularly in one of such high head. Loss of pressure head is guarded against by a contact on the recording pressure gage in the plant which operates a double-contact relay to trip either or both units and shut them down. Such an occurrence might be caused by the load-control float sticking on the high contact and running the load up, or by the relief valves sticking in open position or by sudden cessation of the water supply such as due to a break in the flow line or the screens clogged at the headworks.

Automatic Load Control.—The feature of controlling the load automatically to utilize all the water available without spilling any and without using enough to cause loss of pressure is the most useful device in connection with the plant, as well as the most interesting. It properly comprises three working elements, the float contactor, the timing relays and the actuator. The float contactor is made up in the company shops after the design shown in Fig. 1, which is standard in all semi-automatic plants of the system. The float is installed at the surge chamber with its high contact at an elevation of 6 in. below the spill wall. The float has an operating range of 2½ ft. between contacts. Three No. 6 copper wires lead to the timing relays and contactors in the power house as shown in Fig. 2. These are standard relays adapted to the purpose with only slight modifications. They are wired up as shown in Fig. 3.

It will be noticed that each of the float contact wires leads to a set of contactors and one bellows-type time delay relay. Thence they are common through a motor-operated definite-time relay and a single bellows-type relay, the latter being only an auxiliary to permit the other two bellows-type relays, to reset positively and does not enter into the principle of the thing.

Consider that the upper or high-water contact of the float has closed. One set of contactors and its respective time delay relay are energized simultaneously and the contactors close instantly to operate the actuator motor to pick up some load. In the meantime the time delay relay is operating to close, which it does after a few seconds. Immediately on closing it energizes the motor-operated relay which immediately breaks the circuit to the actuator motor and to the bellows-type relay, which resets. The motor relay continues to operate for several minutes giving the water time to pull down due to the load change. After a certain definite time it breaks its own circuit and resets. Now, if the load change had been insufficient to lower the float off its contact, the operation will be repeated as outlined. However, if the float was off contact nothing would happen until some time later when the lower contact was reached, then the opposite set of contactors would work to effect the reverse operation to drop off some load. Thus it goes up and down, day in and day out, averaging the load that the water is good for and maintaining a fairly constant head.

The actuator, so called, is nothing more than the combination of the governor regulating valve compensating dashpot with its connecting bars and motor-operated screw adjustment. The original principle of operation has been altered to the extent of disconnecting the fly-ball stem from the cross bars and supporting them on a fixed pivot so that they no longer float. This was necessary in order that variations in system frequency would not change the load on the units and defeat to a great extent the automatic load control devices. The flyballs have no effect on operations unless the speed rises more than 10 per cent, as already mentioned. In order that the load control devices will not have any effect on either unit that may have tripped off the bus, or both of them if the plant has tripped off the line, the control circuit is run through auxiliary relays as shown. These

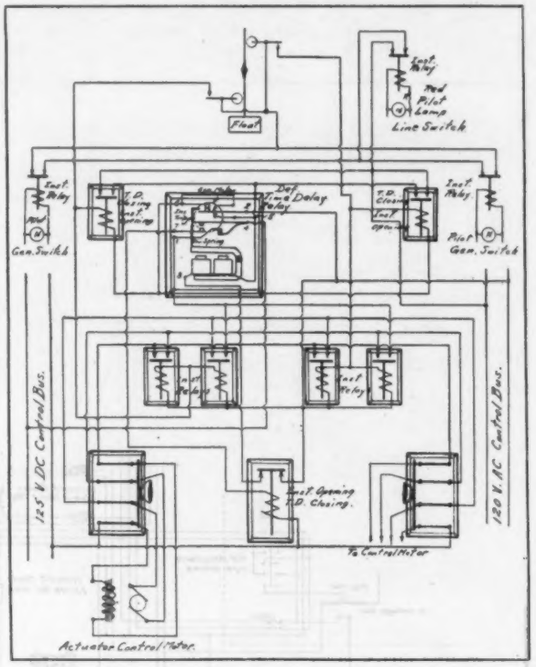

Fig. 9. Relay connections for float load control at Tule power house.

relays are operated across the red pilot lights of the circuit breakers so are energized only when the breakers are closed.

Figure 4 shows one of the governors with its new rigging. In utilizing the governors for the several purposes as outlined it was believed that besides the added reliability there was additional justification for the considerable investment in the governors, because their importance had increased somewhat over the former mode of operation. While it hardly is probable that governors would be purchased for such an installation, the writer believes that some pressure system or power supply reservoir could be better depended upon to shut a unit down than a motor operating from either the a.c. or d.c. bus. Use still is made of the load-limit devices on the governors for limiting the load to a few hundred kw. more than there is water for, which gives the float load control ample margin for its operations.

Protective Relays—Automatic relay protection provided in the Tule plant may be classified as: generator protection (directional over-current relays), generator bus protection (over-current relays), transformer protection (differential over-current relays), line protection (over-current relays), main bearings (temperature relays).

Generator Protection—Figure 5 shows the generator and bus protective relays which are mounted on one panel and in fact combined with each other. Differential protection for the generators would have been preferable, but as it was not practical to bring out the ends of the windings to introduce current transformers in the connection to neutral, the reverse power or directional relays were used. In order to take advantage of as low a current value and time setting as practical without tripping the unit off unnecessarily due to directional surges, the relays were arranged so that the over-current elements were not energized until there was a reversal of power flow. Under this condition the time delay, even though slight, was fully effective. Figure 6 shows how the set of ½-to-2½ amp. low-energy relays was combined with standard 4-to-12 amp. directional over-current relays and an auxiliary contactor in order to serve the dual purpose.

An extra stud was brought out on each directional relay making connection with the wire common to both contacts of same. The directional contacts are connected as shown, with the auxiliary contactor and battery. This contactor normally shunts out the low-current relays. Normally then, current from the generator flows through the current elements of the directional relays which are on comparatively high taps and supposed to function only for severe troubles such as on the generator bus. The directional contacts remain open for normal power flow so that the low-current relays are carrying no current whatever. However, on reversal of power, as for generator trouble, the directional elements close at once and the low-current relays operate very quickly to trip the generator switch which on opening trips the field breaker.

Generator Bus Protection—As already mentioned, the overload element of the directional relays is utilized for the purpose of protecting the generators against troubles that might occur at points not included in the transformer or generator protection such as on the generator bus or leads thereto from the various switches. Inasmuch as the operation of the overload elements of these relays trips the generator switch regardless of directional power flow they become "back-up" relays in case of failure of any of the other relay protection.

Transformer Protection—Three standard low energy ½-to-2½-amp. induction type relays afford protection for the main transformer bank, connected in the usual conventional differential hookup. Bushing-type current transformers were installed on the high-voltage side and the metering transformers on the low-voltage side were utilized for the purpose. The relays operate to trip the line switch and the 2.3-kv. transformer switch.

Line Protection—Three ½-to-2½-amp. over-current relays are connected to a separate set of bushing-type current transformers on the line switch. These operate to trip the line switch only. Being non-directional, however, they also afford back feed protection from the system in event of any plant trouble and failure of other relays to operate. The timing and overload settings of the various protective relays, all of the induction type, are calculated to give proper discrimination and sequence of operation.

Main Bearing Protection—Standard temperature relays are provided for the main generator bearings, the elements being embedded in the babbitt so that the heat transfer will be rapid. The relays operate at a temperature of 100 deg. C. and cause the unit to be tripped off the bus and shut down. In order that any cessation of cooling water supply be noticed at once there are vanes arranged so that the discharge from the cooling coils impinges upon them, keeping the alarm circuit open. The closing of the circuit does not trip the unit off, but merely gives an alarm so that the attendant may rectify the condition before the bearing gets dangerously hot.

Alarm and Signal Facilities—There are installed two 8-drop annunciators, one for each unit, with constant-ringing attachments so that the operation of any device may be automatically designated. A 12-volt storage battery of the lead type is used for all the alarm circuits and for energizing the governor solenoid trips and for tripping the generator switches. This battery is kept charged at a trickle rate by a vibrating type rectifier or it may be charged from the 125-volt control bus through a lamp bank in event of any extraordinary drains. Six-inch vibrating type bells are used for alarm purposes, the alarm circuit being extended to the operator's quarters.

Personnel and Economies Effected—Formerly there were six men regularly employed, in and about the power house: one power house superintendent, three shift operators, one relief operator, one truck driver and general handy man.

Since the installation of the protective equipment and automatic control devices, the requirements are only: one power house operator, one truck driver and general handy man.

The operator is subject to call at night if any of the various protective devices at the plant give the alarm, but sometimes for weeks at a time he is not disturbed at night. The plant "rides out" many system disturbances at night all unknown to the operator. It is estimated that the net saving at the Tule plant on account of the new installation, which cost about $4,000, will be $5,250 per year. Whether any further saving may be effected will be demonstrated over an extended run.

Meter Committee Reports[2]

The meter committee has fostered this year three courses for the education of metermen. These were held at the California Institute of Technology, Pasadena, the University of Arizona, Tuscon, Ariz., and at the University of California, Berkeley. New subjects and lectures have been added to the courses and the attendance has been satisfactory.

. The subcommittee on new developments has been unusually active. Many new and useful devices used in testing and installing meters have been brought to the attenion of the members of the meter committee. These include a micrometer adjustment for test meters, a multi-range potential transformer standard, a new multi-range current-transformer standard, a low-voltage alarm device, watthour meter shelters, a 30-deg. wattmeter, a double-range ammeter, a saturation transformer, a new soldering iron support for meter test benches, an adjustable prop for meter box covers, and a number of types of test facilities for permanent installation in meter boxes.

The subcommittee on meter statistics has completed a survey of the accuracy of meters in the field, tested

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[2] **W. N. Lindblad,** Pacific Gas and Electric Company, chairman. **L. L. Conrad,** Southern California Edison Company, vice-chairman. **Duncan Electric Company:** A. F. Blecksmith. **General Electric Company:** G. P. MacKenzie, W. C. Smith. **Great Western Power Company:** W. G. Knight. **Los Angeles Bureau Power and Light:** J. C. Albert, L. H. Ellerman. **Los Angeles Gas and Electric Corporation:** W. A. McMeekin. **Midland Counties Public Service Corporation:** D. D. Smalley. **Ontario Power Company:** A. J. Hall. **Pacific Gas and Electric Company:** N. P. Carlsen, Jr., R. Crowell, E. L. Hughes, O. A. Knopp, G. H. Searle. **San Diego Consolidated Gas & Electric Corporation:** W. H. Talbot. **Sangamo Electric Company:** L. A. Nott, J. G. Monahan. **San Joaquin Light & Power Corporation:** G. A. Collins, C. F. Gilcrest, M. C. Mitchell. **Southern California Edison Company:** L. H. Beebe, Ernest Ealson, W. R. Frampton, A. S. Price, F. A. Redding, J. H. Vivian. **The Southern Sierras Power Company:** R. G. Jones. **The States Company:** H. M. Thomas. **Westinghouse Electric & Manufacturing Company:** J. E. Bridges, W. F. Grimes. **Western States Gas & Electric Company:** J. C. Abel.

after various intervals. This information should prove of great value in determining proper test intervals.

An investigation of clocks and timing devices was completed. The principle troubles encountered with such apparatus and methods of prevention and cure were discussed. Problems of personnel, organization and records were investigated quite thoroughly.

Under the heading of special tests and investigations a number of interesting and educational papers were presented to the committee. These papers described invstigation of a type removed from the usual run of routine meter tests and include measurements of expansion strains on bus supports, oscillograph investigations on 220-kv. lines, and measurement of temperature gradients in flowing streams by means of thermocouples.

The subcommittee on special metering submitted a report covering several special installations where considerable ingenuity was displayed in solving complicated metering problems. The subcommittee on uniform test facilities has been busy though their report is not yet in completed form. In addition to the local problems, the committee has been of considerable assistance to the N.E.L.A. meter committee in performing certain definite problems assigned to the geographic division committees.

Education of Metermen*

During the spring of 1928 three short courses for metermen were sponsored by the P.C.E.A. meter committee.

The first was given under the direct supervision of Prof. R. W. Sorensen at the California Institute of Technology, Pasadena, March 19-24. The second course was held under the direction of Prof. J. C. Clark at the University of Arizona, Tucson, April 12-14. The third course was given at the University of California, Berkeley, May 21-26, supervised by Prof. T. C. McFarland. Two courses were offered: group "A" for those with limited technical experience, and group "B" for more advanced men. In general, group "B" pre-supposed a knowledge of the subject matter covered by group "A." This year group "B" has been changed to a considerable extent in order to offer inducements to metermen who have taken it up in the past. This course and the one at the California Institute of Technology paralleled each other in the subjects offered as nearly as possible.

These courses are open to anyone interested in electric metering and to employees of any organization. The courses are of great benefit to the electrical industry and in many cases give the men a training which could not be given in any other way except at much greater expense.

* Report of subcommittee of meter committee—R. Crowell, chairman. W. A. McMeekin.

New Developments of Meters*

A "30-Degree" Wattmeter

By L. L. Conrad**

It is frequently desired to determine, for operating purposes, the power flowing in 60-kv. lines to or from certain power houses and substations. The accuracy desired is not great and, where possible, it is desirable to eliminate the expense of high voltage current and potential transformers.

The Southern California Edison Company's test department has solved this problem by utilizing the bushing current transformers usually present in the 60-kv. circuits for supplying current to special wattmeters, potential for which is supplied from the low voltage side of power transformer banks connected to the 60-kv. line. The power banks usually are connected Y-delta or delta-Y in which case the low voltages are 30 deg. out of phase with the high voltages. A special wattmeter is so designed that it compensates for this phase displacement and when properly connected indicates the approximate power on the 60-kv. line.

Another method used was that of interposing a Type MC auto-transformer in the potential circuit. In this case it was not necessary to modify the wattmeter.

Method No. 1—As these instruments are used not only to indicate the approximate amount of power in the circuit but also the direction of flow, it was necessary to make them with the zero in the center of the scale. This necessitated paralleling the current coils of each phase so as to give full reading at full load in either direction of power flow.

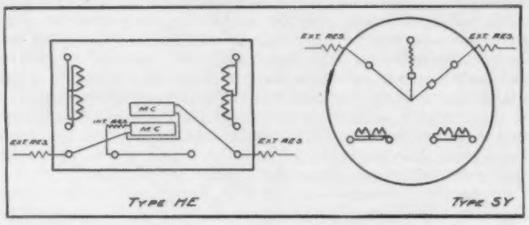


Fig. 1. Internal connections of "30-deg." wattmeter for standard wiring connections.

Each of the potential resistors was reduced until the combined resistance of moving coil and resistor were 57.7 per cent of their original resistance. The meters then were calibrated on a single phase circuit by connecting the current coils in series and potential coils in parallel and applying a potential of 57.7 per cent of the normal potential.

A third resistor of a value equal to the modified

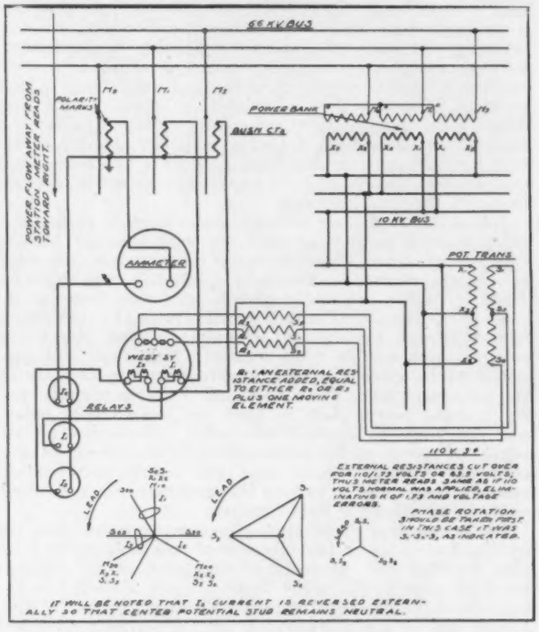


Fig. 2. Connection diagram for "30-deg." wattmeter where only three potential terminal leads are brought out.

resistance of each of the moving coil circuits was then added to form a "Y." The third resistor may be added internally in the meter or externally in a separate box marked for the proper potential post of the meter.

The internal method of connection for Type HE and Type SY meters is shown in Fig. 1. It was later de-

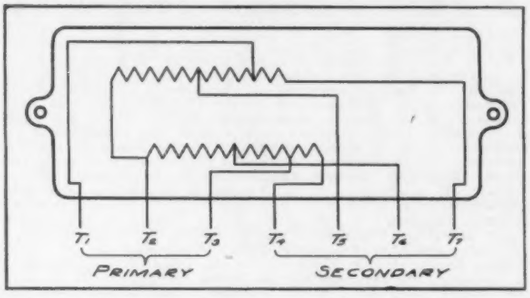


Fig. 3. Internal connections of type MC autotransformer, taps taken off at 50 and 86.6 per cent of winding.

* Report of subcommittee of meter committee—A. J. Hall, chairman.

** Report presented to meter committee.

cided to leave the internal connections of the meters as found and add a third resistor externally. A Type SY meter so connected together with a complete wiring diagram is shown in Fig. 2.

Method No. 2—Fig. 3 shows the internal connections of a Type MC auto-transformer.

By the use of this transformer, the phase displacement necessary can be obtained without alteration of the wattmeter connections. The diagram of connections is shown in Fig. 4.

In using the above wattmeter, it is desirable, owing to the large ratio and phase angle errors of the bushing transformers, to make an overall check of the complete installation in the field where possible. Wherever possible the transformer bank is put on a separate bus

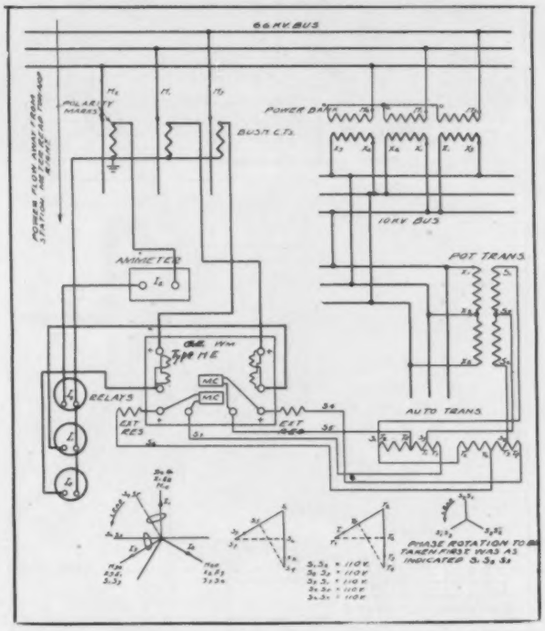


Fig. 4. Connection diagram for "30-deg." wattmeter using type MC autotransformer, when four potential leads are brought out.

with the particular line under test so the special wattmeter can be checked against the wattmeter on the power bank.

Another method used is to determine the direction power is flowing into the station on the line under test and if the station from which the power is coming has a wattmeter that is known to be accurate the "30-deg. wattmeter" may be directly checked by instantaneous readings conveyed over the telephone.

Field men are requested to install these instruments by over-all tests making use of vector diagrams and all sketches and readings are checked and filed in the test department office.

Double-Range Ammeter

By L. L. Conrad*

It is often desirable to know the current in the grounded neutral of a bank of power transformers under normal operating conditions, where a large capacity current transformer is permanently installed in the neutral. The nominal ratio of the neutral current transformer is usually of such a capacity as adequately to provide the ground connection for abnormal conditions imposed on the transformer bank during short circuits on the transmission lines.

The range of switchboard ammeters is, of course, designed and scaled for full scale deflection at the nominal full load rating of the current transformer with which it is to be connected.

Under normal operating conditions this combination of current transformer capacity and the large current values represented by each scale division does not permit anything more than a slight deflection of the ammeter pointer when small ground currents exist.

* Report presented to meter committee.

The accurate indications of these small ground currents are often valuable in the operation of a large network system. The use of an additional current transformer of a lower capacity would provide the accurate indication of the smaller values of ground cur-

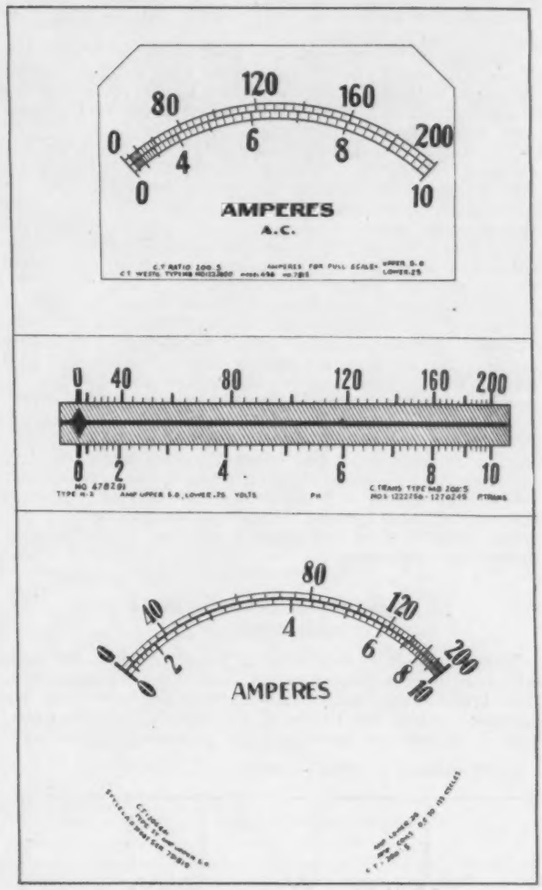


Fig. 5. Scales of double-range ammeters (above) type SY; (center) model No. 496; and (lower) type HE.

rent, but it is obvious that a short circuit or a heavy unbalanced condition on the line would damage the installation, necessitating frequent replacements.

To provide an inexpensive device, an ammeter has been developed recently in the test department of the Southern California Edison Company which meets all the

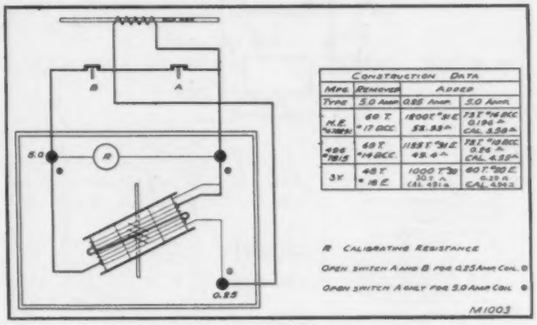


Fig. 6. Internal connections of double-range ground ammeter.

field requirements as specified by the protection engineering department. Model 496, Tpe HE, and Type SY standard switchboard 5-amp. ammeters have been modified by removing the 5-amp. winding from the field bobbin and rewinding with two separate windings.

Modifications to Instruments

The original 5-amp. winding of approximately 60 turns of No. 14 DCC magnet wire is replaced with 1,200 turns of No. 31 bare enameled for the low range (0.25 amp.) coil 1, also 72 turns of No. 18 DCC magnet wire for the high range (5.0 amp.) coil 2. Calibration spools are installed in parallel with 5-amp. coil; a third connection post is provided.

Similar modifications have been made to Model 496, Type HE, and Type SY ammeters with similar characteristics, with the results as shown in the accompanying reproduction of actual scales taken from instruments now in satisfactory service.

In each contemplated installation, an ammeter and current transformer of the proper nominal capacity are sent to the standardizing laboratory for reconstruction of the instrument and scale calibration with the current transformer under field conditions, compensating for all errors due to ratio and secondary burden. The schematic diagram of the internal windings connected to the current transformer is shown in Fig. 6.

The switches A and B are normally closed, thus short circuiting the current transformer secondary leads. Opening switch A removes the short and provides a parallel circuit through coils 1 (0.25 amp.) and 2 (5.0 amp.) for a maximum deflection of the pointer at nominal full load capacity of the current transformer.

Opening switches A and B removes the short and permits current through coil 1 only. The total current in the secondary of the current transformer flowing through the 0.25-amp. winding gives a full scale deflection of the pointer at 5 per cent of the nominal full load capacity of the current transformer, thus giving accurate readings of the ground current under normal operating conditions.

Saturation Transformers

By J. H. Vivian*

Very often it is desirable to have an ammeter that will read over a larger range than the maximum current transformer rating accurately, and yet keep its accuracy within the limits of the current transformers. This is sometimes necessary on grounded neutral circuits to measure normal currents and also fault currents.

* Report presented to meter committee.

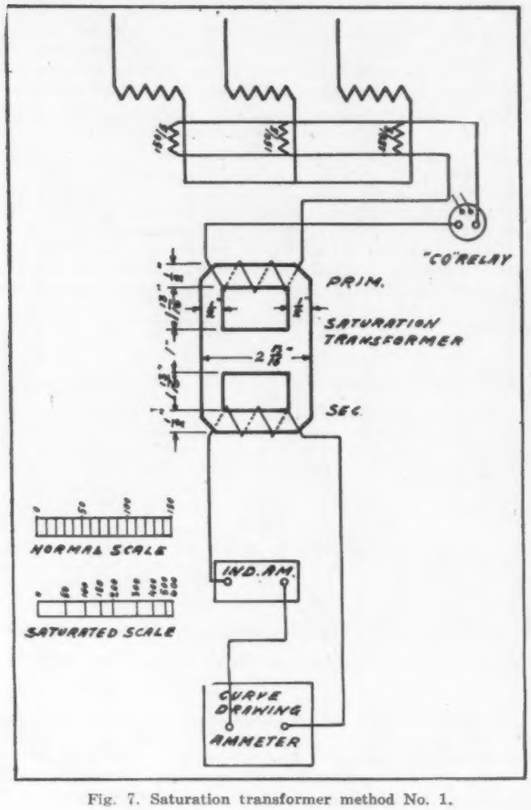


Fig. 7. Saturation transformer method No. 1.

One method used is to make a transformer with very little iron which will become saturated at approximately the full scale of the ammeter. For example, a saturation transformer used with a Model 625 two-speed ammeter (strip chart) having a volt-ampere drop of 10 volt-amperes and main current transformers of 150/5 on the Y side of the power bank, requires 3 lb. of No. 27 B & S gage laminated iron. Iron is from a Type A, Style 125611A current transformer. Primary turns equal 165 of No. 17 DCC; secondary turns equal 22 of No. 17 DCC; 5-amp. primary equals 150 amp. in the main line; 20 amp. primaary equal 600 amp. in line and 5 amp. in meter. Approximately 112 long and 112 short laminations are required. Such a scheme is shown by Fig. 7.

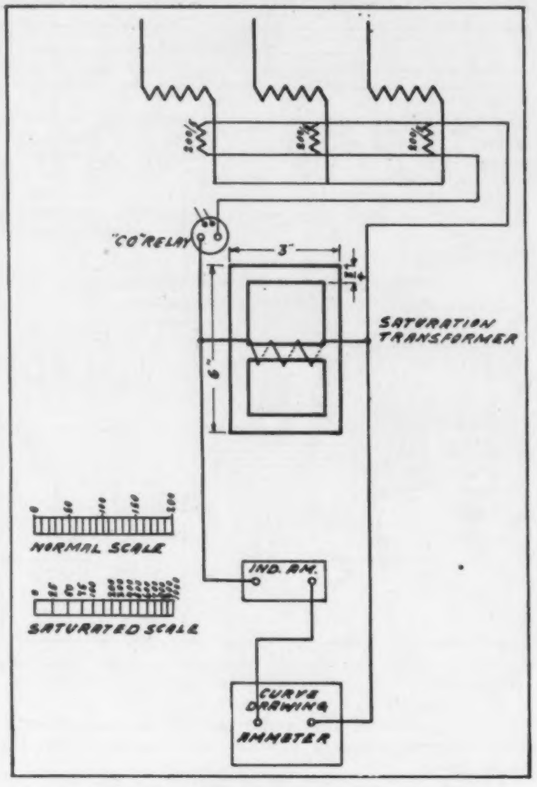


Fig. 8. Saturation transformer method No. 2.

Another method which may be used is to make a similar core as in Fig. 7, but wound with one winding only and connected as shown in Fig. 8. If this is connected in the neutral circuit as shown it will also record over a large range accurately. The heavier the burden the more iron will be needed. Turns may be added or subtracted as found necessary. For example, with an indicating ammeter and a Type C7 ammeter connected in the circuit as shown with 200/5 current transformers, it requires approximately 3 lb. of iron with 24 turns of No. 8 copper wire to give a deflection of 1,000 amp. full scale with 5 amp. flowing through meters, the core in this case being approximately 6 x 3 in. and about ¾ in. wide.

Either installation should be checked in the field by overall test where the proper number of turns is determined.

Multi-Range Current Transformer Testing Equipment

By O. A. Knopp*

This equipment supersedes and supplements earlier constructions reported in the national meter committee report of 1924-25.

The equipment is built in two units:

* Report presented to meter committee.

1. For testing current transformers of 5 to 500-amp. capacity.
2. For testing current transformers of 600 to 3,000-amp. capacity.

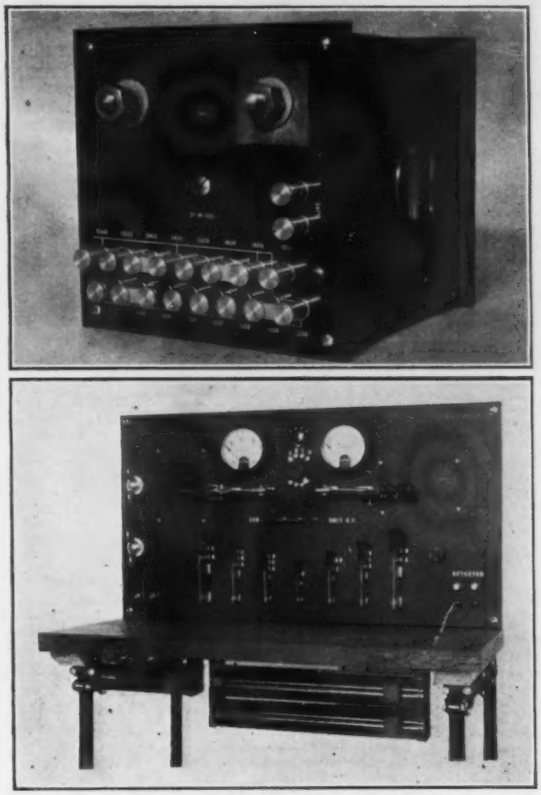


Fig. 9. (Above) Multi-range current transformer testing equipment for 600 to 3,000 amp. (Lower) Same for from 5 to 500 amp.

5 to 500-amp. Unit—This unit has the following ranges: 5, 10, 12.5, 15, 20, 25, 30, 40, 50, 60, 75, 80, 100, 125, 150, 160, 200, 250, 300, 400, and 500. amp. It is complete in every respect for the ratio and phase angle test of the above rated current transformers, embodying a current supply transformer, multi-range standard, rheostats, instruments, switches, and panel mounted on a bench ready for connection to a three-phase 220-volt supply, as shown in picture (Fig. 9).

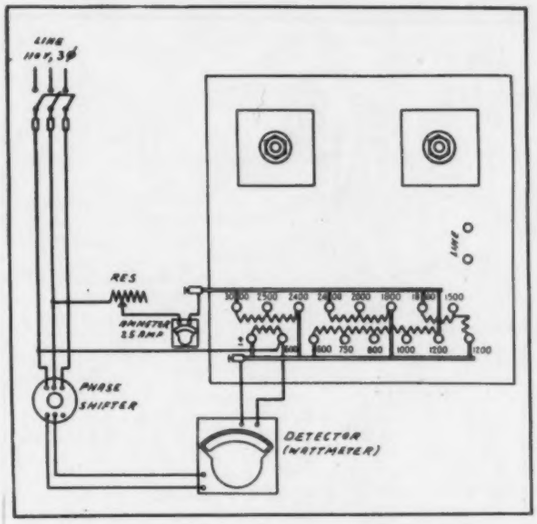


Fig. 10. Connection diagram for determining ratio and phase angle of 600 to 3,000-amp. multi-range current transformer standard.

The standard muti-range current transformer is of such design that the ratio and phase angle correction is the same for all ranges. It is possible to determine this absolutely without any reference standard by calibrating it in itself by means of the "one to one" method.

The Silsbee set can be used with it but is not needed as the Silsbee deflection method using a special detector wattmeter (reported in Serial Report No. 267-92) together with a chart makes it possible to determine ratio and phase angle without computation and with higher accuracy.

600 to 3,000-amp Unit—This unit has the following ranges: 600, 750, 800, 1,000, 1,200, 1,500, 2,000, 2,500 and 3,000 amp. to 5 amp. It is built with a loading transformer into one compact unit about 10x 10x 11 in. (See Fig. 9a.)

Provisions are made for absolute calibration of all ranges by means of the "one to one" method, permitting a very close standardization. (Fig. 10.)

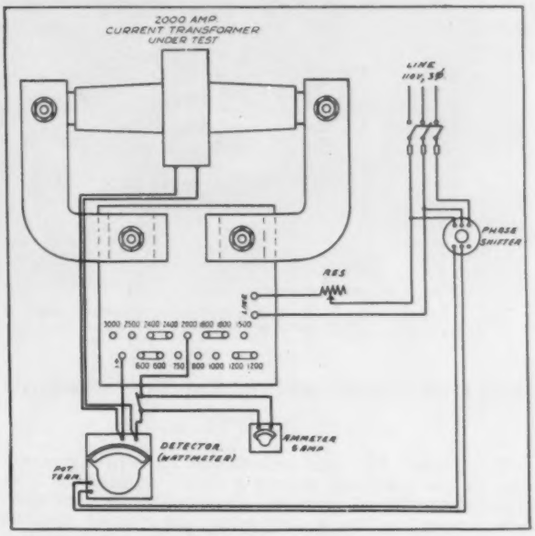


Fig. 10-A. Connection diagram for determining ratio and phase angle of a 2,000-amp. current transformer with 600-3,000 amp. multi-range current transformer testing equipment.

A maximum current of 5 amp. is drawn from a 220-volt, three-phase supply. This is transformed to the proper value for the current transformer by means of a step-up current transformer (Fig. 9a), which is a part of the equipment, to the proper value for the current transformer under test. The Silsbee deflection method of comparison between the transformer under test and the standard transformer is used, employing the detector type of wattmeter, mentioned above, to determine the difference. (See Fig. 10a.)

Multi-Range Potential Transformer Standard

By O. A. Knopp*

This standard (Fig. 11) supersedes earlier constructions of more limited range, reported in the national meter committee report 1924-25.

The standard has the following ranges: 110, 220, 440, 1,100, 2,200, 4,400, 6,600, 11,000 to 110 volts. It provides an absolute standard since it can be calibrated without any reference standard by means of the "one to one" method (110 to 110 volts), using the same detector wattmeter mentioned above for current transformer calibration.

The windings are designed so as to give the same ratio and phase angle connection for all ranges within a few hundredths of 1 per cent on ratio and one to two minutes on phase angle. Therefore, after standardization potential transformers of any of the above ratings can be calibrated with great precision by either the Brooks deflection method, using the above mentioned detector wattmeter, or the Silsbee Null method.

* Report presented to meter committee.

The standard is mounted in a steel tank 12x12 in. and 10 in. deep with bakelite top. Handles are provided for conveniently moving it in the laboratory.

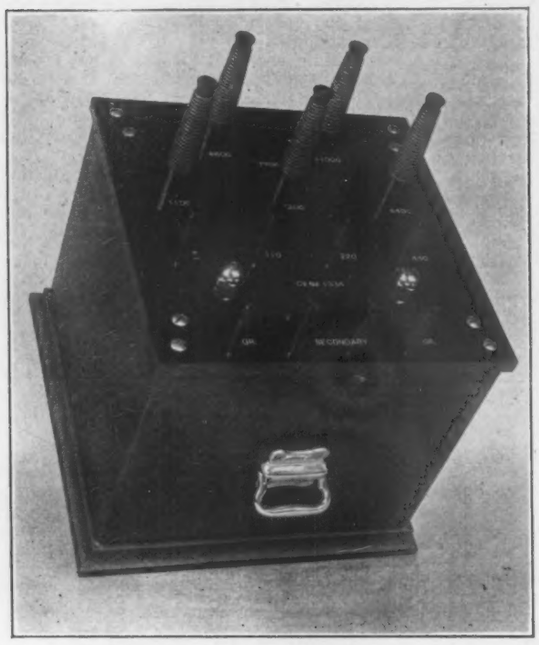


Fig. 11. Multi-range potential transformer standard rated 110-220-440-1,100-2,200-4,400-6,600-11,000/110 volts.

Full Load Adjustment for Rotating Standards

By O. A. Knopp*

The present full load adjustment on rotating standards is too coarse to permit a closer adjustment than .5 per cent without spending an undue amount of time. The reason for this is that when the magnet claming screws are loosened, the magnets change their position relative to the disk before any adjustment is made with the magnet adjusting screw. The adjustment of the standard to closer limits than, say .1 per cent, is largely

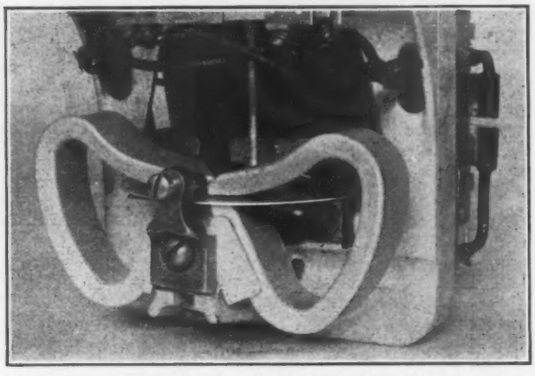


Fig. 12. Micro adjustment applied to type I-B-6 rotating standard

a matter of chance and is a slow and tedious operation.

In order to make it possible to make definite adjustments of the smallest order, a little bronze bracket is placed in front of the magnets as shown in Fig. 12. A small iron screw can be fed into the gap between the magnets, similar to the full load adjustment of the Type I-10 meter. The dimensions of the screw and thread are such that one turn of the screw changes the speed of the standard one-tenth of 1 per cent.

* Report presented to meter committee.

Soldering Iron Fixture for Meter Test Boards

By O. A. Knopp*

During the process of testing meters on lagging power factor it is necessary in many types to increase or decrease the external resistance of the lag coils. This necessitates the unsoldering and resoldering of the wire where the joint is made.

An electric soldering iron is very convenient for this work, but since the duty on the iron is very light, an iron would overheat and burn out if left across 110 volts throughout the day. We have, therefore, been using a standard iron with a 32-cp. carbon light or an equivalent resistance cut in series with the iron on 110-volt circuit.

However, we have experienced considerable difficulty with the cord of such an iron being rather inconvenient. Often when caught, it pulls the iron onto the floor caus-

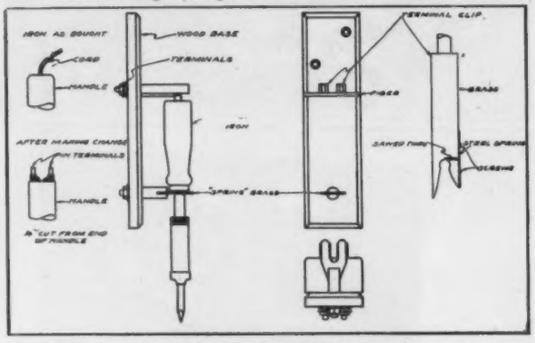


Fig. 13. Soldering iron holder and connection rod.

ing no little damage. We have, therefore, devised a block which can be mounted on the support under the test bench as shown in the accompanying blue print. The iron is held in the spring clips and energy is delivered to brass terminals, and we have found the iron to be very convenient for the testman. (See Fig. 13.)

* Report presented to meter committee.

Meter Cabinet Door Prop

By J. E. Klose*

A great many meter cabinets are hinged at the top causing no inconsiderable loss of time to the meterman who must look around for a temporary prop to hold the door open while he is testing. The door prop shown in Fig. 14 can be very easily made up, and is light and portable.

* Report presented to meter committee.

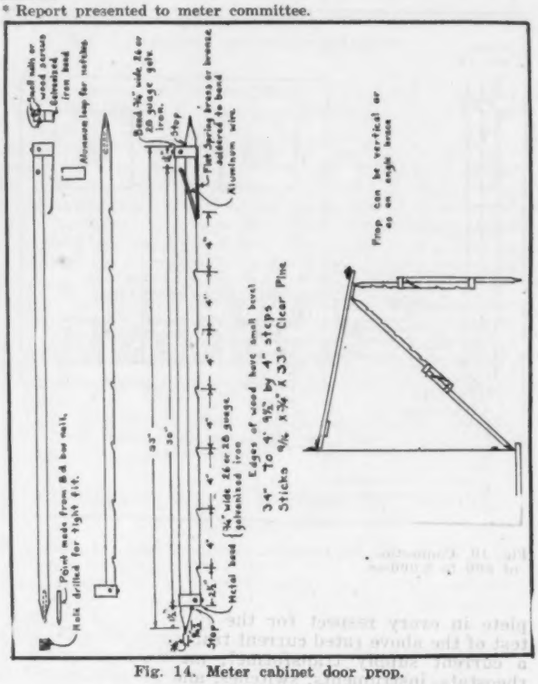


Fig. 14. Meter cabinet door prop.

Clocks and Timing Devices*

A questionnaire was mailed to all utility companies who are members of the P.C.E.A. and the following report is a summary of answers received:

Clocks and timing devices, being instruments to measure time or time intervals, are so closely related to other instruments used for measuring purposes that it is the unanimous opinion and practice of the utility companies in this district to handle all tests and maintenance of such equipment in the test and meter departments, the work being directly under the supervision of an experienced clock and instrument mechanic in the larger companies. The smaller companies having a small number of clocks or timing devices have repairs made by a reliable firm employing clock mechanics. When the work is done in the meter and test departments the instrument mechanic usually has one or two men working with him in more or less the capacity of apprentices who are able to take care of all timing devices with the possible exception of those containing very small or delicate escapements. This includes stop-watches which would require a watch mechanic and it is the practice of all companies to send this class of work to a high class jeweler.

The following classes of clocks and timing devices are used:

TABLE 1—Clocks and Timing Devices.

Cycle Counters	Westinghouse cycle counter General Elec. cycle counter States Co. cycle counter
Maximum Demand Timing Devices	Duncan Elec. Co. Sangamo Elec. Co. General Elec. Co. types M-4 to M-10 Westinghouse Co. type OA
Stop Watches	Jockey Club Lurch Special Omega Warden Meylan
Time Switches	Campbell Hartford Paragon Anderson General Elec. T-5, T-6 Sauter Tork States
Curve—Drawing Meters	Esterline Westinghouse type U Westinghouse type RA General Elec. C-4, C-7 General Elec. CR-2 General Elec. P-4, PS-4 Chelsea clocks in stream flow recorders Bristol Foxboro
Wall Clocks	Seth Thomas
Special	Eclipse time stamp 20-minute cycle clock International time recorder clocks Waltham clocks for watchmen Bailey instrument clocks Water-height indicators

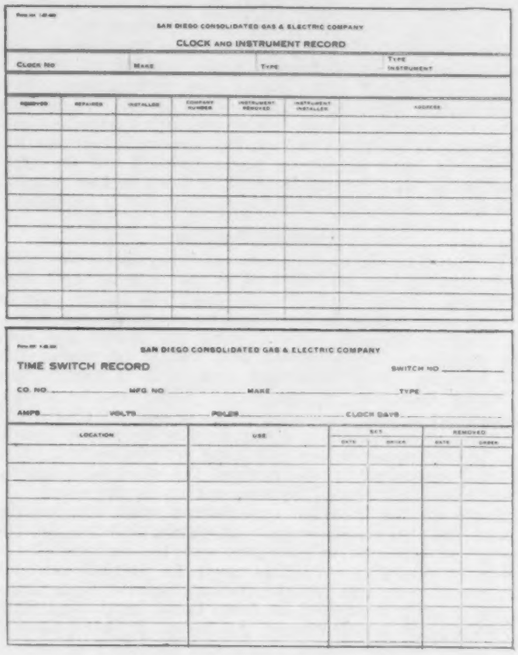
The general practice is to make repairs when the replacement of parts and the labor involved does not exceed approximately 75 per cent of the cost of new equipment. This depends on the value of the clock or the difficulty of making replacements. Where a stock of repair parts is carried and it is possible to make quick repairs, the work is done regardless of cost.

All new clocks and watches should be inspected when received to see if properly oiled and in good running condition.

A complete card record should be made of all clocks and all instruments containing clocks, showing the date purchased and history of the instrument. The card should be such that a history could be followed throughout the life of the equipment. This system is in use at the present time by the San Diego Consolidated Gas and Electric Company, San Diego, and the Southern California Edison Company, Los Angeles. The accompanying illustration shows Card No. 1, a record of the clock, and Card No. 2, a complete record of the time switch.

It seems that the importance of the maintenance of clocks and time switches in the field has been overlooked by most companies. This is a very important part of the work necessary for the successful operation of clocks and time switches in service. It is the practice of some, however, to have a man trained in the care and maintenance of such instruments while in service. His duties are to wind and service, install and remove, and keep all instruments in a satisfactory condition at all times. If a clock or switch does not operate properly and cannot be made to operate correctly it is returned to the shop where the clock and instrument mechanic makes the necessary repairs.

In summarizing the troubles which develop from time to time, it is not the intention to compare the operation of one instrument or clock with another, but to try and enumerate those troubles that do develop and the various methods used to overcome them. It is necessary to mention various types as each has individual characteristics and is developed for a certain class of work and has given good satisfaction where properly serviced. The chief troubles with clocks in the past have been due to an unsatisfactory system of maintenance. Those encountered are caused by dirt, broken jowels, loose jewels, worn metal bearings, broken balance staffs, distorted balance springs, broken main springs, loose pallets, worn balance wheel bearings, worn and rusty balance staff pivots, dampness due to


SAN DIEGO CONSOLIDATED GAS & ELECTRIC COMPANY

CLOCK AND INSTRUMENT RECORD

Clock No. | Make | Type | Type Instrument

Removed	Repaired	Installed	Company Number	Instrument Removed	Instrument Installed	Reasons

SAN DIEGO CONSOLIDATED GAS & ELECTRIC COMPANY

TIME SWITCH RECORD — Switch No.

Co. No. — Mfg. No. — Make — Type

Amps. — Volts — Poles — Clock Days

Location	Use	Set Date	Set Order	Removed Date	Removed Order

Fig. 1. Record card for clocks and instruments (above). Record card for time switches (below). Space and rulings on back of each for remarks and notes on settings.

water, and winding arbors ruined by winding with pliers.

One of the first things that should be done is to install properly a clock or instrument where it will be free from dirt and protected from the weather. This simple precaution will prevent the accumulation of dirt or dampness, one of the primary causes of worn and clogged bearings. Dampness causes the steel parts to rust and rust enters the bearing causing the grinding effect which throws the gears out of alignment and the pivots are either bent, broken or have ridges worn in them. Dirt or rust will wedge the pivots in the bearings so that they will not revolve, thereby stopping the clock. These are the principal causes of all clock trouble. If installed as suggested and given a cleaning and oiling at least once every two years very good results should be obtained. There are installations, however, which should be serviced more frequently and the fact never should be overlooked that it requires an expert clock and instrument mechanic to perform this work satisfactorily.

Specific Data

No. 1—A Time Switch—These are the most universally used for switching purposes and have given very

* Report of subcommittee of meter committee—W. H. Talbott, chairman.

satisfactory service. The troubles experienced are usually due to the action of the switch part as very little trouble occurs in the clock when given proper care.

No. 2—A Circular-Chart Clock—The chief troubles are wear in the bearings and pinions and broken main springs. These parts are easily obtained and a stock should be kept on hand.

No. 3—A Roll-Chart Clock—This timepiece is very delicate, but will operate in a satisfactory manner if carefully installed in a suitable location, one which should be free from dust and vibration. In some cases the supporting sides have been milled and a brass plate installed to enclose the main part of the clock to make it more dustproof. While there are a number of different conditions that will cause trouble, some of those which are most serious are friction in the reset mechanism, friction in the torque compensator, charts binding and the misalignment of gears due to improper installation of the clock in the meter case. Unless the clock is installed in a manner that will prevent the gears binding, trouble surely will develop. While this clock requires very careful attention due to the importance of its work, if given proper care satisfactory service will be obtained.

In order to decrease the cost of maintenance of this type of clock the Southern California Edison Company has endeavored to obtain quotation on a full-jeweled (11 jewels) escapement in which the jewels would be of the plate type which are held in place with small screws instead of being peened into the brass. The latter process crystalizes the brass, making an accurate job very difficult after about two replacements have been made. Such an escapement can be purchased at a very reasonable price in lots of not less than six dozen. This entails quite an outlay, but the manufacturer has agreed to keep all repair parts (which will be interchangeable in all escapements) in stock in Los Angeles and this is a decided advantage. The cost is nominal.

Demand Meters

In handling demand meters and registers the same procedure should be followed in the field as with time switches. These instruments should be taken care of by one man whose duties would be to change the charts on graphic demand meters, wind the clocks and read the registers. This person also should be responsible for keeping these important meters in a satisfactory working condition in the field. This can be accomplished by a thorough inspection of all working parts at least once a month, a simple way in which trouble can be overcome before anything serious occurs. If a clock is required to be changed the clock and instrument mechanic should be sent out to do the work.

Some of the troubles experienced with various demand meters are corrosion of parts, friction in the clutch or set-back mechanism, and the failure of the clock to operate. Weights used to control set-back and weights on the demand indicators have been found to be heavily corroded, in some cases scale was built up to a point which caused the weight to bind against the worm on the motor shaft and the staff of one of the other gears. This causes a heavy friction which prevents the register from working properly. As this has been discovered only recently, a permanent cure for the trouble has not been found as yet. In some of the more severe cases the corrosion has been entirely removed and the weight coated with lacquer. Weights attached to the demand indicator corrode and the flakes fall on the disc causing the meter to stick. This corrosion apparently was due to the acid used in soldering the indicators to the plates. This is overcome by thoroughly cleaning and washing and then applying lacquer. Troubles due to friction are found in several of the different types and makes and are prevented to a certain extent by the instrument mechanic completely adjusting before the instrument is placed in service. Repairing, adjusting and cleaning of all timing devices should be handled by the clock and instrument mechanic, or an assistant.

Graphic Voltmeters

Graphic voltmeters at feeder centers should be taken care of by a clock and instrument mechanic, or an assistant, who should be held responsible for keeping these in a satisfactory working condition at all times. It also should be his duty to change the charts and wind the clocks once each week. In making these weekly trips to each station the mechanic should be able to ascertain any immediate trouble and correct it. This is important because usually the entire voltage of a system is regulated according to information obtained from the charts of these instruments.

There are a number of special timing devices and systems which are interesting. One such installation is an automatic frequency control used by the Southern California Edison Company in the Long Beach steam plant. The equipment consists of a "frequency recorder" with an adjustable contact on a slide-wire drum which can be set to make contact at any predetermined variation from the standard frequency. These contacts are connected through relays to operate circuits of the governor control motors on the steam turbines and operate in parallel with, and in the same manner as, the hand control on the switchboard. The relay operating circuit includes an interrupter which is mounted on the cam shaft of the recorder. This interrupter sends the current to the motor in a series of short impulses effectively preventing hunting and over-travel.

For checking standards there are several systems in use. The one in use by the Bureau of Tests and Inspections of the Pacific Gas and Electric Company is a ratchet-and-solenoid arrangement operated from a pendulum that beats in thousandths of an hour and which is used for starting and stopping rotating standards. This was described in a 1923-24 N.E.L.A. meter committee report.

Satisfactory results can be obtained by a manually operated time switch in the potential circuit, employing an accurately adjusted second-beating clock whose pendulum is plainly visible. Enlarged and elongated "second" markings on the second dial, when properly illuminated and the visibility increased by a properly adjusted optical lens, make possible an accurate time count in seconds. The position of the pendulum with reference to its total oscillatory motion is utilized as the final point of "on" and "off."

The test department of the Southern California Edison Company now contemplates acquiring a timing device which utilizes a synchronous tuning fork and rotary converter with a specially designed relay for operating the potential circuit. The relay is to be equipped with an adjustable time-interval mechanism to provide a wide range of "on" and "off" intervals. The consistency of the tuning fork may be relied upon within the limits of its temperature coefficient. With constant voltage and temperature the accuracy of the device is expected to within 0.02 and 0.05 per cent.

Some of the other companies are contemplating the installation of devices for testing standards. The efforts of this committee have been to provide a source of exchange of ideas whereby an understanding could be arrived at which would enable all concerned to reduce maintenance costs and give better service.

Special Tests and Investigations*

Flashover Investigation on 220-kv. Lines

By L. L. Conrad**

During the early winter of 1926 numerous flashovers occurred on the 220-kv. Big Creek lines of the Southern California Edison Company which caused faulty relay operations. As these relay operations were of such varied nature and in some cases without apparent reason, causing the protection engineering department great difficulty in specifying the proper relay setting, it was decided to conduct an investigation with respect to the magnitude of the ground currents during the flashover period.

As the cause of the flashover and the instant that it might occur were of an indeterminate character and impossible to anticipate, it was necessary to provide some device which would record the values of ground current and in which part of the secondary network they existed. So by necessity some photographic device appeared to be the only type of apparatus which would meet the requirements, and the oscillograph was accepted as being the most generally applicable to the problem. Several articles have been published in the past by various manufacturing companies describing specially designed photographic recording devices which could be manufactured on order for this investigation, but as this procedure would cause considerable delay in obtaining the desired information it was

* Reports of subcommittee of meter committee—O. A. Knopp, chairman. L. L. Conrad.

** Report presented to meter committee.

decided to utilize some existing and immediately available apparatus.

Two standard three-element oscillographs, regular test department equipment, were at hand for immediate use, which, with some modifications, could be put

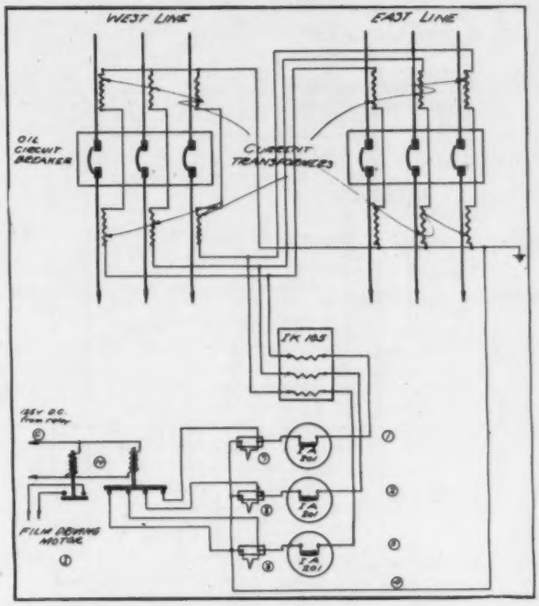


Fig. 1. Differentially connected current transformers used in oscillograph investigation of Laguna Bell 220-kv. lines.

into service with the least delay. One oscillograph was selected because of its portability, compactness, the simplified illuminating system and its permanent field arrangement.

A study of the field conditions during flashover periods revealed that the time duration of transients was from one to four seconds; this necessitated that some consideration be given to the length of film to provide sufficient length of record per cycle for analytical purposes.

printed, gave an oscillogram over 40 in. in length. The mitted the use of an endless film which, when cut and

A special film magazine was made which perdesign of the magazine included two 8-in. drums spaced 10 in. apart and enclosed in a light tight metal container. An adjustable idler was used to compensate for the slight diffierences in the length of film and provide the proper tension to prevent slippage. A light tight aperture opening and safety shutter similar to that on the standard film magazine is provided permitting use on a standard oscillograph.

During the laboratory experimental work considerable difficulty was experienced in devising a suitable means of fastening the film into an endless belt, due principally to the reason that the structure of ordinary kodak film stock is of quite a different nature from motion picture film stock. This difference was immediately noted when an attempt was made to splice the kodak film with film cement in the same manner as is used very satisfactorily in the splicing of motion picture films. Various film cements were tried with the same general results. The end of the film from which the emulsion was removed soon softened under the action of some constituent of the film cement reducing it to a gelatine condition of very little strength which allowed the film to separate at that point under the slightest tension.

This difficulty was remedied by the reinforcement of the splice by adhesive tape or gummed paper attached to the hard side of the film, which in no way interfered with the photographic record because the emulsion side of the film was always on the outside of the film belt running close to the aperture in the magazine.

In future investigations where continuous film operation is necessary it is planned to construct a large drum to which the film can be permanently attached by means of small clamps around the edges on the face of the drum.

This procedure will remove some of the difficulties encountered in running a long film continuously for several days. In the two-drum magazine it was found inadvisable to allow the film to run continuously at a film speed of 1 ft. per second for a period of over 24 hours.

On account of the importance of an early installation it was impossible to manufacture the magazine as a precision device, consequently the small inaccuracies in the alignment of the two drums permitted the film to have a tendency to weave laterally on the drums during its travel, similar to a leather belt seeking the highest pulley surface. During a period of 18 to 20

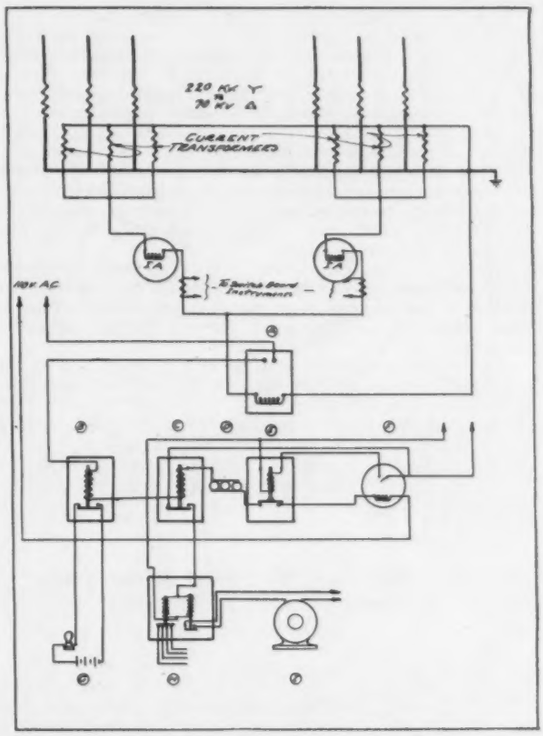


Fig. 2. Connection of control devices used in oscillographic investigation.

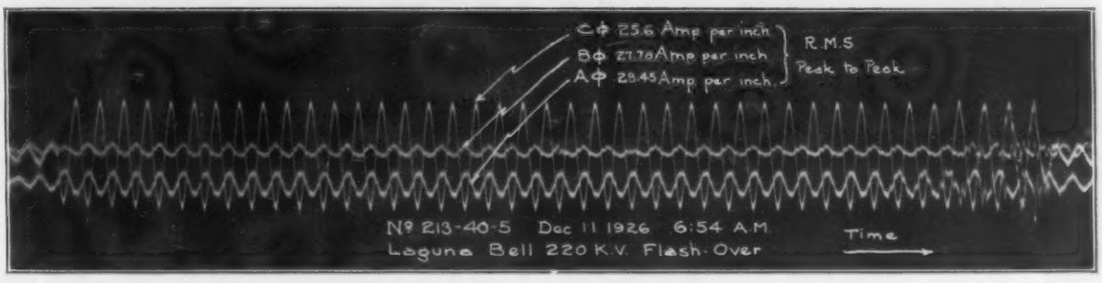

C Φ 25.6 Amp per inch
B Φ 27.70 Amp per inch
A Φ 28.45 Amp per inch.
R.M.S
Peak to Peak
Nº 213-40-5 Dec 11 1926 6:54 A.M.
Laguna Bell 220 K.V. Flash-Over
Time

Fig. 3. Oscillogram of 220-kv. flashover.

hours of operation this weaving would cause a slight roughening of the film edges which would naturally result in either the rough edges catching at the aperture or the film would mount the turned edges of the drums, in either case stopping the film.

The field installation was made at Laguna Bell, the southern end of the 220-kv. Big Creek transmission line. Reference to Fig. 1 of the accompanying prints will show schematically the application in the secondary circuits of the differential connected current transformers on the east and west line oil circuit breakers, V_1, V_2 and V_3 representing the oscillograph vibrator elements in series with the current elements of the IK105 and IA201 relays installed on lines Nos. 1, 2 and 3.

Fig. 2 shows schematically the initiating and control devices in the secondaries of the ground current transformers which are installed on the high potential side of the 220 to 70-kv. star-delta transformers.

Relay A represent a low energy CO relay which with a close adjustment of contacts operates with a small ground current. The contact of A energizes a circuit through the operating coils of relays B and C, a lamp load D, relays E and F. The operation of B energizes the oscillograph lamp G which allows a beam of light to be reflected from the vibrator mirrors on to the sensitized film.

The operation of B and C is simultaneous. C in turn operates relay H which, as shown, energizes the film driving motor I and at the same time removes a short circuiting device from the leads to the oscillograph permitting the transient current to flow through the vibrators thereby exposing the moving film.

E is a non-automatic manual reset disconnecting relay, operated by the closure of the contacts on a CO relay F which is given a time period adjustment of four seconds. The operation of E opens the current control circuits which de-energizing B extinguishing the light G, also opens the contacts of C which de-energizes the operating coil of H which replaces the short circuit device on the vibrator circuit and stops the motor I.

Relay E being normally closed and manually reset prevents any re-operations which might destroy the record of the previous operation if such re-operations should occur after one exposure and prior to the exchange of the film holders.

The short circuiting device at H protects the vibrators from any damage which might result from excessive current under switching surges or other causes at times when there is no transient current in the vibrator circuits.

Shunts permitting 50 amp. to flow in lines 1, 2 and 3 were put across the elements to protect the vibrators from excessive current.

The accompanying oscillogram (Fig. 3) shows that a satisfactory record can be obtained under the above conditions, the apparatus operating automatically at 6:54 a.m. clearly showing that the incoming transient started the motor and lamp prior to the heavy current surge.

Phase Angle and Potential Drop in the Secondary Leads of Potential Transformers*

Long leads in the secondaries of potential transformers, unless the size of conductor is larger than ordinarily used, introduce appreciable errors in the registration of watthour meters. With a secondary burden consisting of two watthour meters and a directional relay potential coil, a 300-ft. run of 19-25 stranded cable will introduce a phase shift of between 15 and 20 minutes. This phase angle, in the case of an inductive secondary burden on the potential transformer, is in the same direction as the phase angle of the potential transformer and the two add in their effect on the registration of the watthour meters. If, in addition to the two watthour meter and relay potential coils, a non-inductive burden of the order of 200 volt-amperes is added to one of the phases its potential will be lowered about 2 per cent and that of the other phase raised somewhat. In this case considerable error is introduced by the voltage drop, and there is also an appreciable phase shift.

The watthour meter method of testing instrument transformers can readily be adapted to measuring the phase angle and potential drop in the secondary leads of potential transformers. Fig. 1 is a diagram of the connections for determining the potential drop and phase angle of leads B2 and C3 for phase BC. A and B are the two watthour meters; F and G, two double-pole double-throw switches; h and i, a pair of leads from the

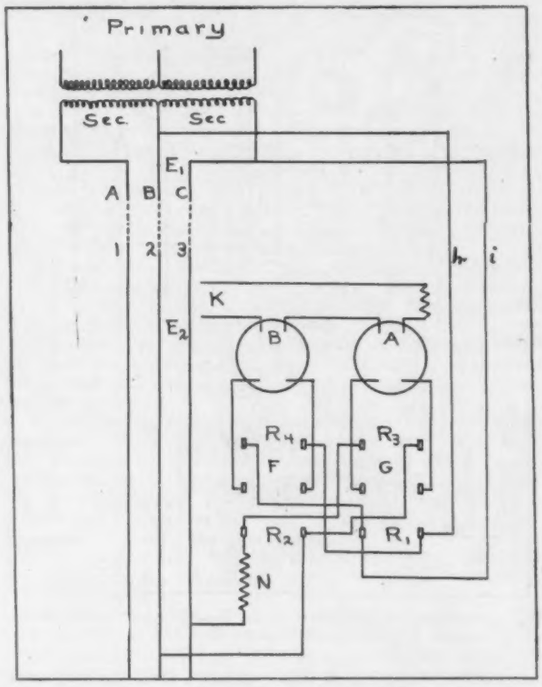


Fig. 4. Connections for testing phase angle and potential drop in secondaries.

potential transformers to the switchboard; N, a resistance equal to that of the leads h and i; and K, a source of current for the series elements of the two watthour meters. The resistance and inductance of the leads h and i should be kept low by using a good sized con-

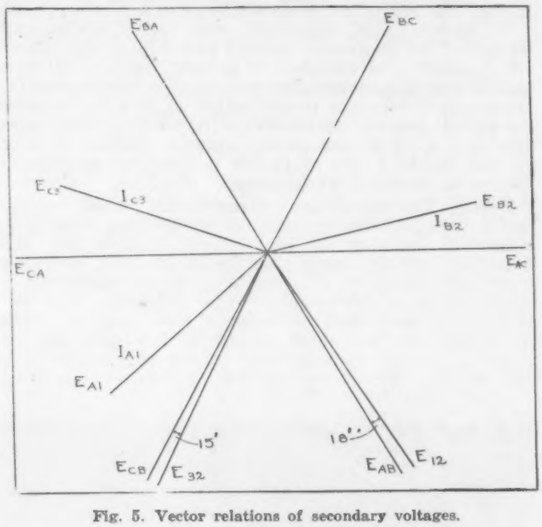


Fig. 5. Vector relations of secondary voltages.

ductor, about No. 10, and twisting or tying the two together.

With the current in the series coils of the watthour meters in phase with the potential BC, two sets of readings are taken; first, with the switches F and G in the positions R_1 and R_2 the revolutions of the meters A and B being designated R_1 and R_2, respectively; and, second, with the switches in the positions R_3 and R_4, the

* Report presented to meter committee.

revolutions of A and B being designated R_3 and R_4. Then

$$\frac{E_1}{E_2} = \sqrt{\frac{R_1 R_4}{R_2 R_3}}$$

which is the ratio of the voltage at the transformer terminals to that at the switchboard.

To get the phase difference of E_2 and E_1, the current in the series coils of the watthour meters is made to lag behind the potential BC and another set of readings is taken, from which

$$\cos(\theta + a) = \cos\theta \frac{E_1}{E_2} \sqrt{\frac{R_2 R_3}{R_1 R_4}}$$

θ is the angle by which the current in the series coils of the meters lags behind the potential BC, $\frac{E_1}{E_2}$ is the ratio, found in the first test, of the voltage at the transformer terminals to that at the switchboard, R_1, R_2, R_3, R_4 are the readings of the two watthour meters, and a is the difference in phase between E_1 and E_2. This form of the phase angle formula is convenient for logarithmetic calculation and leaves no question as to the sign of a, or need of further tests to determine it. E_2 leads E_1 if the sign a is positive.

To check the accuracy of the method a set-up, as shown in Fig. 1, was made, $\frac{E_1}{E_2}$ and a determined by the watthour meter method of test and the results checked by calculation. The burden across each of the two phases (1-2, and 2-3) consisted of two watthour meters and a directional relay potential coil. The resistance of the lead A-1 was 0.479 ohm; B-2, 0.492 ohm; and C-3 0.472 ohm. The current in leg C-3 was 0.463 amp. and lagged 79 deg. and 45 min. behind potential E_{CB}. The current in leg A-1 was 0.518 amp. and lagged 79 deg. and 17 min. behind potential E_{AB}. The phase sequence was CBA, potential AB leading potential CA 120 deg., and potential CA leading BC 120 deg. Both phase voltages, AB and BC, were 120.5 volts.

The ratio of the voltage at the transformer terminals to that at the switchboard $\frac{E_1}{E_2}$, for phase AB as determined by test was 0.9990. The result obtained by calculation (see calculations) was 0.9993. The phase shift for this phase obtained by test was + 19 min. and by calculation + 18 min. For the other phase, $\frac{E_1}{E_2}$ by test was 1.0023 and by calculation, 1.0026; and the phase shift by test + 18 min. and by calculation + 15 min.

Calculations

E_{AC}, Fig. 2, has the initial or zero phase position.

I_{C3} lags 79 deg. and 45 min. behind E_{CB} and has the phase position 160 deg. 15 min.

$$I_{C3} = i_{C3} + j i_{C3}$$
$$= -0.43576 + j\ 0.15646$$
$$E_{C3} = I_{C3} R_{C3} = (i_{C3} + j i_{C3}) R_{C3}$$
$$= -0.20568 + j\ 0.073846.$$

I_{A1} lags 79 deg. and 17 min. behind E_{AB} and has the phase position 220 deg. 43 min.

$$I_{A1} = i_{A1} + j i_{A1}$$
$$= -0.39262 - j\ 0.33790$$
$$E_{A1} = I_{A1} R_{A1} = (i_{A1} + j i_{A1}) R_{A1}$$
$$= -0.18807 - j\ 0.16186.$$
$$I_{B2} = I_{3C} + I_{1A} = -I_{C3} - I_{A1}$$
$$= +0.82838 + j\ 0.18144$$
$$E_{B2} = I_{B2} R_{B2} = (i_{B2} + j i_{B2}) R_{B2}$$
$$= +0.40757 + j\ 0.089269.$$

E_{12}, the switchboard value of phase voltage AB,

$$= E_{1A} + E_{AB} + E_{B2}$$
$$= e_{1A} + e_{AB} + e_{B2} + j(e_{1A} + e_{AB} + e_{B2})$$
$$= +60.84564 - j\ 104.10493$$

the absolute value of E_{12}

$$= [(60.84564)^2 + (104.10494)^2]^{\frac{1}{2}}$$
$$= 120.58 \text{ volts.}$$

The ratio of the transformer terminal voltage to the switchboard voltage

$$\frac{E_{AB}}{E_{12}} = \frac{120.5}{120.58} = 0.9993$$

The angle by which E_{12} differs from E_{AB},

$$= \text{tangent}^{-1} \frac{-104.10493}{+60.84564} - 300 \text{ deg.} = +18 \text{ min.}$$

E_{32}, the switchboard value of phase voltage E_{CB},

$$= E_{3C} + E_{CB} + E_{B2}$$
$$= e_{3C} + e_{CB} + e_{B2} + j(e_{3C} + e_{CB} + e_{B2})$$
$$= -59.63675 - j\ 104.34064$$

The absolute value of E_{32}

$$= [(59.63675)^2 + (104.34064)^2]^{\frac{1}{2}}$$
$$= 120.18 \text{ volts.}$$

The ratio of the transformer terminal voltage to E_{32}

$$= \frac{120.5}{120.18} = 1.0026$$

The angle by which E_{32} differs from E_{CB},

$$= \text{tangent}^{-1} \frac{-104.34064}{-59.63675} - 240 \text{ deg.} = +15 \text{ min.}$$

Results of Heating and Expansion Test on Indoor 6.6-kv. Bus

By R. G. Jones*

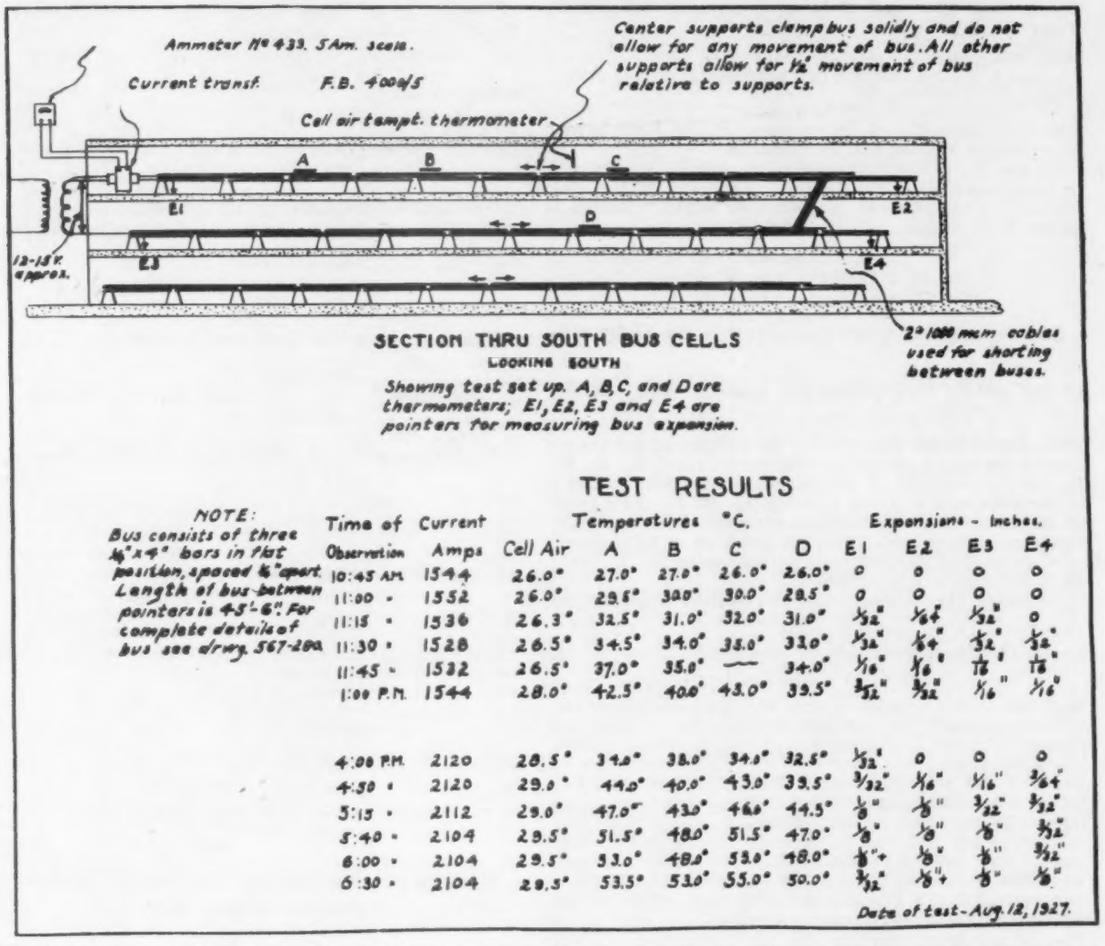
The test was made on two phases of the south bus. The two phases were shorted at one end of the bus, and a large current capacity transformer connected at the other end, with the necessary current transformer and ammeter. Pointers were arranged at the ends of each bus for accurately measuring any expansion that might occur. Theormometers were placed at different points along the bus for determining bus temperature. One termometer was suspended in the bus cell for determining air temperature.

A preliminary two-hour test was made with a bus current of a little over 1,500 amp. At the end of two hours the cell air temperature had gone up 2 deg. C., the bus temperature had risen approximately 15 deg. C., and each half of the bus had expanded about 3/32 in.

It was the intention to make the main test with a bus current of 3,000 amp., but after considerable experimenting it was found impossible to obtain this current with the equipment on hand. A current of a little over 2,100 amp. was the maximum obtainable, so that this was the current used in the test. The test was run for two and one-half hours, at the end of which time there was a 1½ deg. C. rise in the cell air temperature, a 20 deg. C. rise in bus temperature and an expansion of ⅛ in. for each half of bus.

The accompanying drawing shows the test set-up and results obtained. Thermometers A and C were steel encased which may account for the higher readings as compared with thermometers B and D, which were without cases. There were no cell doors in place to interfere with air circulation in the bus cells. As these doors are only partly screened, they may reduce ventilation a slight amount which would increase the air cell temperature under normal operating conditions. The results would indicate that the allowance for bus expansion which was made ½ in. for each half of bus was more than ample, and also that the bus had suffi-

* Report presented to meter committee.


Ammeter #° 433. 5 Am. scale.
Current transf. F.B. 400a/5
Cell air tempt. thermometer
Center supports clamp bus solidly and do not allow for any movement of bus. All other supports allow for ½" movement of bus relative to supports.
A
B
C
D
E1
E2
E3
E4
12-15 V. approx.
2-0 1000 mcm cables used for shorting between buses.
SECTION THRU SOUTH BUS CELLS
LOOKING SOUTH
Showing test set up. A, B, C, and D are thermometers; E1, E2, E3 and E4 are pointers for measuring bus expansion.

TEST RESULTS

NOTE: Bus consists of three ¼" x 4" bars in flat position, spaced ¾" apart. Length of bus between pointers is 43'-6". For complete details of bus see drwg. 567-20a

Time of Observation	Current Amps	Temperatures °C. Cell Air	A	B	C	D	Expansions - Inches. E1	E2	E3	E4
10:45 A.M.	1544	26.0°	27.0°	27.0°	26.0°	26.0°	0	0	0	0
11:00 "	1552	26.0°	29.5°	30.0°	30.0°	28.5°	0	0	0	0
11:15 "	1536	26.3°	32.5°	31.0°	32.0°	31.0°	1/32"	1/64"	1/32"	0
11:30 "	1528	26.5°	34.5°	34.0°	35.0°	33.0°	1/32"	1/64"	1/32"	1/32"
11:45 "	1532	26.5°	37.0°	35.0°	—	34.0°	1/16"	1/16"	1/16"	1/16"
1:00 P.M.	1544	28.0°	42.5°	40.0°	43.0°	39.5°	3/32"	3/32"	1/16"	1/16"
4:00 P.M.	2120	28.5°	34.0°	38.0°	34.0°	32.5°	1/32"	0	0	0
4:30 "	2120	29.0°	44.0°	40.0°	43.0°	39.5°	3/32"	1/16"	1/16"	3/64"
5:15 "	2112	29.0°	47.0°	43.0°	46.0°	44.5°	1/8"	1/8"	3/32"	3/32"
5:40 "	2104	29.5°	51.5°	48.0°	51.5°	47.0°	1/8"	1/8"	1/8"	3/32"
6:00 "	2104	29.5°	53.0°	48.0°	53.0°	48.0°	1/8"+	1/8"	1/8"	3/32"
6:30 "	2104	29.5°	53.5°	53.0°	55.0°	50.0°	3/32"	1/8"+	1/8"	1/8"

Date of test - Aug. 12, 1927.

Fig. 6. Method and results of test on indoor 6.6.-kv. bus to determine amount of heating and expansion for different values of bus currents.

cient current carrying capacity for all operating conditions without overheating. There was no audible or visible expansion of the bus except at the pointers.

Electrical Measurement of River Temperatures

By W. R. Schneider*

The apparatus described herein was built for the purpose of determining the water temperatures at various points of certain selected cross-sections in two California rivers.

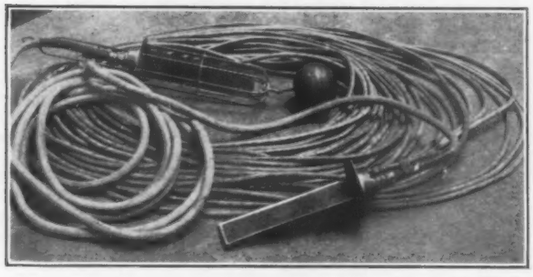


Fig. 7. Thermo-couple assembly.

The thermocouple method of measuring temperatures was chosen as it required the minimum amount of special apparatus, and had the advantage of giving very reliable results. The use of a potentiometer for making the measurements had the following advantages:

1. The readings were not affected by changes in the resistance of the thermocouples.
2. The readings were not affected by changes in the lead resistance which was at an unknown temperature.
3. The readings were not affected by the contact resistances of the connections at the instruments. These connections were made and broken repeatedly during each test.

Ten thermocouples were connected in series in order to increase the reading accuracy obtainable with the portable instruments that were used. Portability was one of the prime requisites.

The thermocouples were made of flexible copper and advance wire. The copper wire was No. 22 cord. Each flexible advance wire was made by drawing ten No. 33 advance wires into a piece of small sleeving. Each of these wires was 24 ft. in length. Ten of each were connected in series so as to give ten thermocouples on each end of a 25-ft. cable.

The couples at each end were laced to a thin piece of mica, covered with an envelope of thin mica, and the whole enclosed in a 0.015-in. water-tight copper jacket. The cable connecting the two thermocouple heads was enclosed by a ½-in. rubber tube. A No. 16 rubber covered duplex cable, 250 ft. long, was connected to one head to carry the potential to the measuring instruments on the bank.

The thermocouples were formed directly on the ends of the wires that were carried through the cable so as to avoid the insertion of another conductor into the circuit which would set up parasitic emf. A 10-lb. weight was attached to the exploring couple when tests were made in a moving stream, to prevent the couple being carried downstream. In order to avoid damage to the exploring couple by snags and rocks on the river bottom, the exploring couple was surrounded by a guard as shown in the accompanying illustration. These thermocouples had a time lag of about 30 sec. Couples in which the time lag was reduced to a few seconds by

* Report presented to meter committee.

exposing the thermocouple junctions directly to the water were not very satisfactory. The leakage of current between the exposed junctions was not constant, and the readings therefore slightly variable.

The emf. of the thermocouple was measured on the bank of the river with a portable potential indicator.

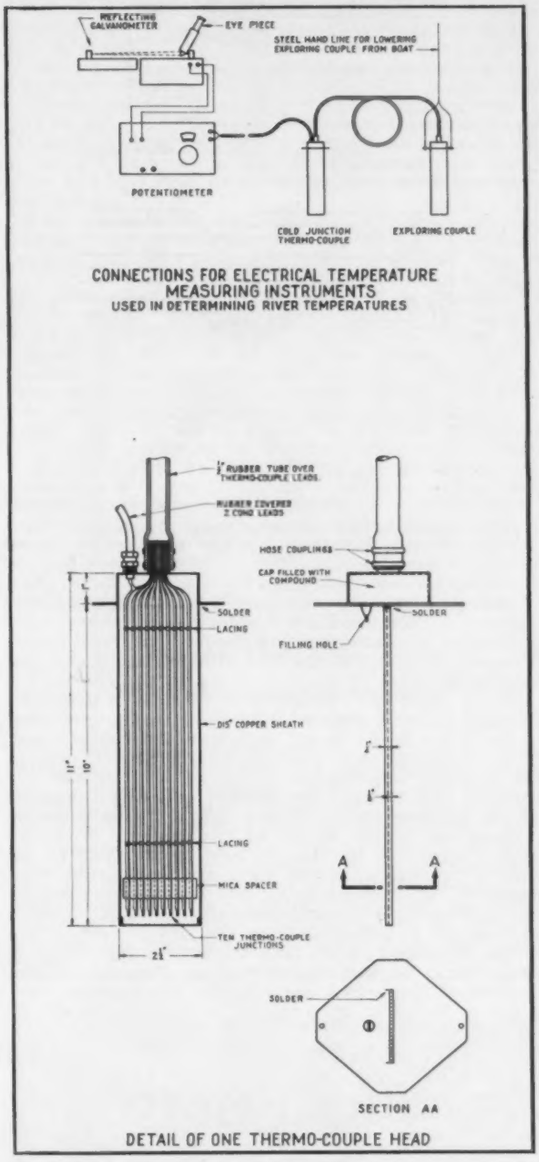


Fig. 8. Construction and connection details of thermo-couple head used for measurement of river temperatures.

This indicator had a shunt placed across the slide wire so that the two full scale capacities were reduced from 14 and 70 m.v. to 0.7 and 7.0 m.v. The galvanometer supplied with this instrument was not sufficiently sensitive when operated on the new low ranges and was removed and a portable reflecting galvanometer used in its place.

With the aforementioned apparatus each division on the low range of the potentiometer (140 divisions for the full scale) represented a temperature difference between the two thermocouples of 0.013 deg. C. On the upper range each division represented 0.13 deg. F. The entire equipment was calibrated in the laboratory with a thermometer graduated to 0.01 deg. C. The readings were taken in the following manner:

A steel cable marked at 5-ft. intervals was stretched across the river at a suitable location. The thermocouples were placed in a boat and the necessary apparatus connected on the bank. One thermocouple was placed in a heat insulated can hung into the water over the stern of the boat. This was taken as the standard reference temperature of the cold junction and was measured with a calibrated thermometer. This cold junction temperature was read at the beginning and end of each run across the river. The exploring couple was lowered to various depths in the river by a marked cable. In crossing the river the readings were taken at approximately 20-ft. intervals.

Special Metering*

A very general response was made to the questionnaire sent out for information in regard to methods of handling kva.-hr., summation, four-wire three-phase, and special demand metering. It was to be expected,

* Report of subcommittee of meter committee—G. A. Collins, chairman.

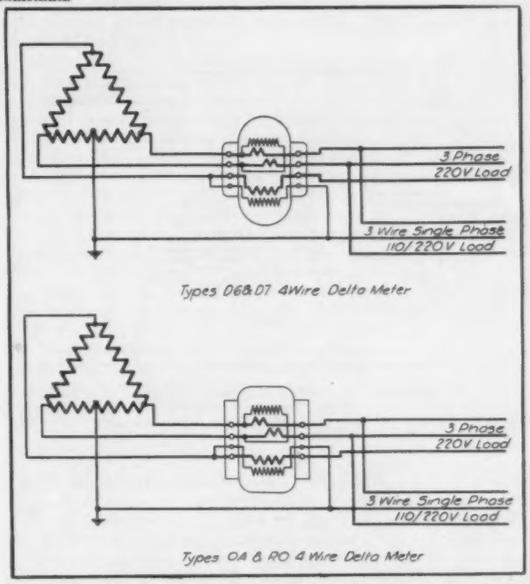

3 Phase 220V Load
3 Wire Single Phase 110/220V Load
Types D6&D7 4Wire Delta Meter
3 Phase 220V Load
3 Wire Single Phase 110/220V Load
Types OA & RO 4 Wire Delta Meter

Fig. 1. Connections for metering 3-phase, 3-wire, 220-volt load combined with single-phase, 3-wire, 110/220-volt load without instrument transformers; 220-volt, 4-wire delta, polyphase meters with separate terminals.

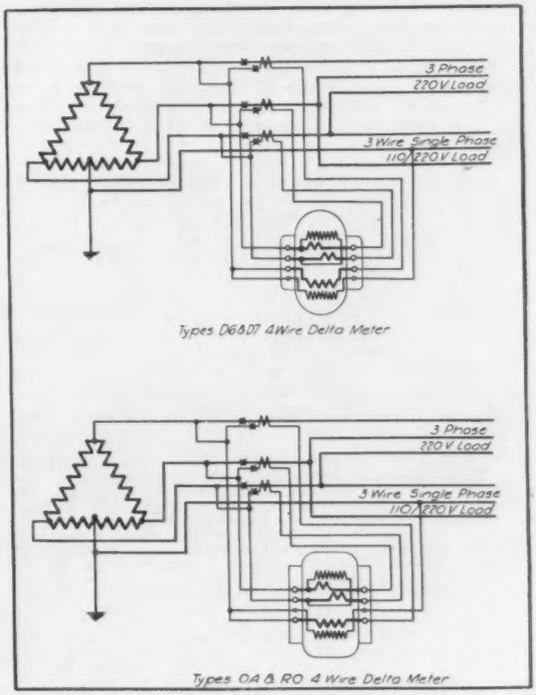

3 Phase 220V Load
3 Wire Single Phase 110/220V Load
Types D6&D7 4Wire Delta Meter
3 Phase 220V Load
3 Wire Single Phase 110/220V Load
Types OA & RO 4 Wire Delta Meter

Fig. 2. Connections for metering 3-phase, 3-wire, 220-volt load combined with single-phase, 3-wire, 110/220-volt load, with current transformers; 5-amp., 220-volt, 4-wire delta, polyphase meters with separate terminals.

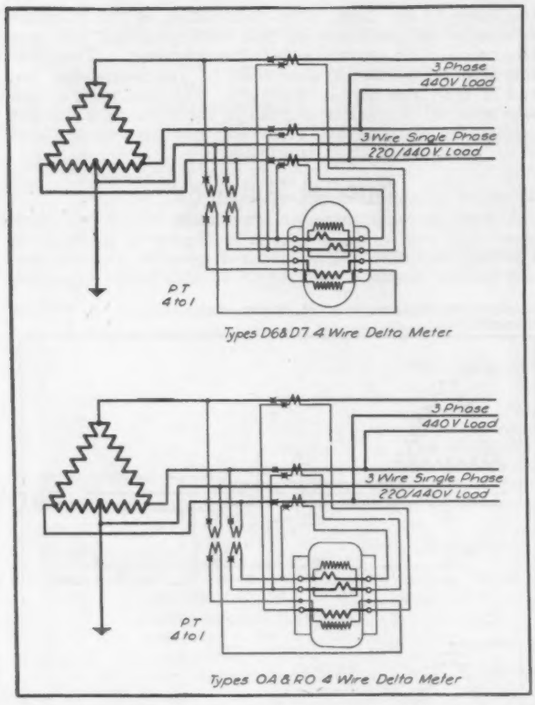


Fig. 3. Connections for metering 3-phase, 3-wire, 440-volt load combined with single-phase, 3-wire, 220/440 volt loads; 5-amp., 110-volt, 4-wire delta, polyphase meters with separate terminals.

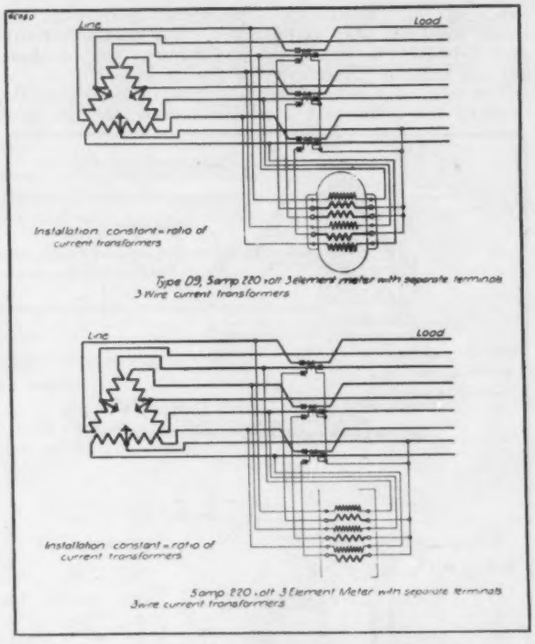

Line
Load
Installation constant = ratio of current transformers
Type D9, 5amp 220 volt 3 element meter with separate terminals 3 Wire current transformers
Line
Load
Installation constant = ratio of current transformers
5amp 220 volt 3 Element Meter with separate terminals 3wire current transformers

Fig. 4. Connections for metering three single-phase, 3-wire, 110/220-volt loads with one meter; load supplied from 3-phase bank.

however, that much of the material received would cover methods already well known.

The diagrams in Figs. 1, 2 and 3 illustrate a method developed by the Pacific Gas and Electric Company for metering on one meter a three-phase power load and a three-wire single-phase load. The upper element of a two-element polyphase meter has been replaced by a single-phase three-wire meter element of corresponding current and voltage rating. In Fig. 4 is shown their method of metering with one three-element polyphase meter three single-phase three-wire loads from a three-phase bank of transformers. One company is metering the same kind of installation with six current transformers, the secondaries of the two current transformers, on each phase having their secondaries paralleled and connected to an element of a three-element polyphase meter.

In connection with summation metering the Hydro-Electric Power Commission of Ontario reports the use of multiple primary auxiliary current transformers. The use of these auxiliary current transformers avoids paralleling the secondaries of the circuit current transformers and permits the use of a 5-amp. meter for totalizing.

A new method of metering kva. has been developed in which there is produced a direct current proportional to the watts in the circuit by a standard method; and, in a similar manner, another current proportional to the reactive volt-amperes in the circuit. These two currents pass through one element of a Kelvin balance of the dynamometer type and each produces a torque proportional to the square of the current. Thus we have a torque on the balance arm proportional to the sum of the squares of the watts and the reactive volt-amperes. This torque is opposed and balanced out by means of another dynamometer type element in which the current is proportional to the square root of the torque developed by it; thus we have a third current proportional to the square root of the sum of the squares of the active and reactive volt-amperes, and which is, therefore, proportional to the volt-amperes in the circuit.

Overhead Systems Committee Reports[2]

The work of the overhead systems committee has been handled by the subcommittee method, each subject under study assigned to such a committee under the leadership of its chairman, who has been responsible for gathering data and presenting it at the several meetings in the form of progress reports. The subjects handled were as follows:

Distribution transformer loading, K. B. Ayres.
Corrosion of metals in line construction, N. P. Carlsen, Jr.
Pole-line structures and devices, R. G. Boyles.
Pole-line construction tools and equipment, F. E. Dellinger.
Joint-pole practice and construction rules, R. E. Hill.
Standard pin and insulator threads, L. J. Corbett.

In addition to the above a joint subcommittee was appointed with the inductive co-ordination committee to

[2] **H. H. Minor,** San Joaquin Light & Power Corporation, chairman. **R. G. Boyles,** Southern California Edison Company, vice-chairman. **Aluminum Company of America:** W. C. Lynch. **The California Oregon Power Company:** R. S. Daniels, O. G. Steel. **City of Glendale:** P. Diederich. **Coast Counties Gas & Electric Company:** A. E. Strong, W. R. Van Bokkelen. **Coast Valleys Gas & Electric Company:** T. W. Snell. **Detrick-Joslyn Company:** H. N. Pratt. **Electric Power Equipment Company:** C. E. Ingalls. **Farnham & Cunningham:** R. E. Cunningham. **Garland-Affolter Engineering Company:** P. H. Affolter. **General Electric Company:** D. I. Anzini, Fred Garrison. **Graybar Electric Company:** J. E. Crilly. **Great Western Power Company:** M. N. Clark, G. H. Hagar, F. H. Klippel. **Kortick Manufacturing Company:** J. M. Culverwell. **Line Material Company:** F. J. Gleiss. **Los Angeles Bureau Power and Light:** H. L. Caldwell, G. A. MacDonald. **Los Angeles Gas and Electric Corporation:** F. E. Dellinger, E. R. Northmore, G. A. Riley. **Los Angeles Joint Pole Committee:** J. E. Macdonald. **W. N. Mathews Corporation:** B. C. Holst. **Maydwell & Hartzell:** H. F. Hartzell. **Midland Counties Public Service Corporation:** D. D. Smalley. **National Mill & Lumber Company:** C. F. Cooper. **Ohio Brass Company:** J. B. Naugle. **Ontario Power Company:** C. W. Walter. **Pacific Coast Steel Company:** G. E. Honn, H. G. Sharp. **Pacific Gas and Electric Company:** H. H. Buell, N. P. Carlsen, Jr., L. J. Corbett, R. R. Cowles, P. J. Freygang, W. T. Hannum, C. E. Larrabee, E. A. McGinty, Joseph Mini, Jr., W. D. Skinner, L. B. Smith, E. H. Steele, A. J. Theis, J. O. Tobey, Roy Wilkins, C. E. Young. **Pacific State Electric Company:** B. W. Baldwin. **Pacific Telephone and Telegraph Company:** S. W. Kephart. **San Diego Consolidated Gas & Electric Corporation:** K. B. Ayres, A. S. Glasgow. **San Francisco Joint Pole Association:** R. E. Hill. **San Joaquin Light & Power Corporation:** E. R. Banks, E. J. Crawford, R. V. Hall, H. N. Kalb, C. W. Lightner, C. C. Wilson. **Southern California Edison Company:** C. F. Andrews, W. P. Champion, R. B. Guilbault, N. B. Hinson, J. F. Hodges, Harold Michener, G. E. Nott, H. L. Sampson, E. R. Stauffacher. **The Southern Sierras Power Company:** P. W. Greenleaf. **Taper Tube Pole Company:** C. A. P. Duffie. **Truckee River Power Company:** V. D. Armstrong. **Westinghouse Electric & Manufacturing Company:** S. L. Case, W. P. L'Hommedieu. **Western States Gas & Electric Company:** H. W. Clark, E. S. Moreland.

study the feasibility of the use of a common primary and secondary grounded neutral. This is being carried on with the help of N.E.L.A. headquarters and the American Telephone and Telegraph Company, and should result in very conclusive data as to the possible interference that such a system will cause with communication circuits and the remedial measures necessary to overcome this interference. Also the economics of the problem are being studied to determine if the benefits to the power companies will offset the possible additional cost to which the communication interests may be put. This problem is of great importance and the study is being very carefully made. It was reported at the Fresno meeting that good progress was being made and that most of the preliminary work had been completed.

The subcommittee on standard pin and insulator threads was appointed to help the N.E.L.A. overhead systems committee in its study of this subject. This is an outgrowth of a start that was made by the P.C.E.A. two years ago. A great many data were obtained by the committee and these were turned over to the N.E.L.A. committee as it was felt that the subject was national in scope. It was reported at the Louisville meeting of that committee that very good progress was being made and that a satisfactory standard for both 1-in. and 1⅜-in. threads would soon be formulated.

Two very interesting papers on accident prevention were presented before the overhead systems committee. This plan of joint meetings with the accident prevention committee is a new arrangement and has proved most beneficial. It should be continued.

The reports of the studies made this year follow in detail. They represent a great deal of work by the subcommittee membership and it is believed will be of value to all having to do with overhead line construction and operation.

Transformer Loading—Ratio of Connected Load to Demand

By K. B. Ayres*

The endeavor of the committee is to tabulate data received from members to give a ready reference which will show within reasonable limits the ratio between the connected load and the demand for light and for power for many different classes of business.

Of course it must be borne in mind that the demands shown in this report represent one set of conditions only, and these conditions in a power installation will be greatly varied by the prosperity of the industry being served at the time the demand is taken. In lighting installations, particularly in hotels and apartment houses, it will be varied by the percentage of occupancy. It has been the endeavor to show in the tabulation approximately the percentage of occupancy of the hotels and apartment houses so that it may, to some extent, be used as a guide in correcting the demand figures. Then also there is the condition of excessive loads due to special attractions, opening nights, etc., which may occur only once or at very infrequent intervals.

It is found in the tabulation of the data received that a great many installations are fed not from independent transformer stations, but from secondary mains. While the practice of the utilities serving these places (as to the transformer capacity which would be installed to carry this particular load) is not evident, still the ratio of connected load to demand is shown and should be of considerable value. This really is the heart of the study.

These data cover installations of many kinds including hospitals, department stores, welding and machine works, dairies, rock-crushers, office buildings, packing houses (both walnut and citrus), laundries, canneries (both fruit and fish), ice companies, irrigation pumps, newspapers, hotels, apartments, theaters, etc., and it is believed that when the final analysis is made the results will prove well worth the effort.

It is deemed advisable to include in this report, mention of some of the devices used in procuring the figures here shown and those used for the purpose of giving a constant indication of load or temperature. Many of the tests shown were made with current transformers and recording ammeters while others were made with split coils and special indicating ammeters. Some are the results as recorded by maximum-demand instruments. It is not the intention of this report to go into a discussion of the comparative merits of the several methods of test as the percentage of error in any one of them is not sufficient to be objectionable in carrying on tests of this nature.

Of those instruments giving a constant indication of load or temperature there are two general types both dependent upon the temperature of the oil in the transformer for their indication, which may be either in degrees of heat or in the operation of a semaphore. One type of this class of instrument is a thermometer which registers oil temperature only. The other has an additional thermometer actuated by the ambient temperature and working in series with the one actuated by the oil temperature, thereby giving an indication of per centage of safe load.

There has been one study of transformer heating made by R. V. Hall of the San Joaquin Light & Power Corporation which will be incorporated complete in this report. Mr. Hall's report is accompanied by numerous curves showing the rise and fall of the temperature in the windings of the transformers due to different load

* Report presented to overhead systems committee.

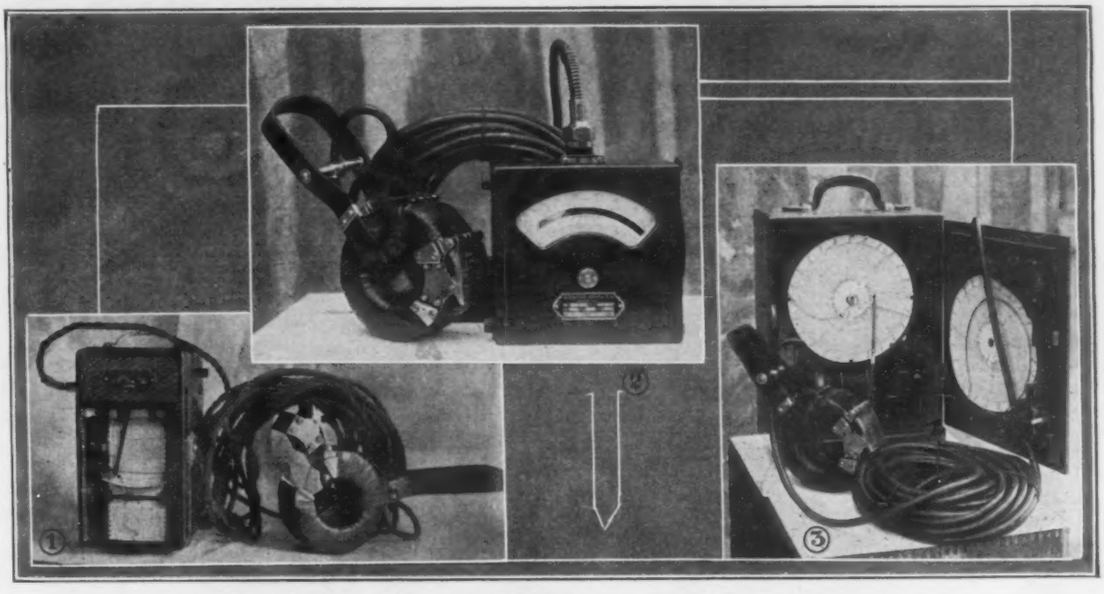


Fig. 1. Various types of portable metering equipment used in the "demand-factor" survey.

TABLE I—Relation between Load and Demand.

Class of Business	Connected Load KW		Transformer Installation KW		Demand KW		Time of Demand	Percent Occupancy	Percent of Demand to Connected	
	Lights	Power	Lights	Power	Lights	Power			Lights	Power
68 Hospital	78.00	35.00	1–100	3–15	41.00	10.40	.....	.....	52.6	29.70
70 Hospital	.....	137.00	.....	67½	.....	61.00	.....	.....	.....	44.50
71 Hospital	18.00	8.00	1–25	1–15	6.00	7.00	.....	.....	33.3	87.50
72 Hospital	.....	170.00	1–50	43	24.40	126.00	.....	.....	.....	74.20
66 Hospital	115.60	161.00	.....	.....	41.00	38.10	7:15 p.m.	.....	35.7	23.60
1 Hospital	160.00	134.00	3–100	.....	112.00	112.00	.....	.....	70.0	83.50
56 Hospital	65.80	94.50	.....	.....	19.80	33.60	8:00 p.m.	.....	30.2	35.60
73 Department Store	118.00	109.00	100	3–25	101.00	56.00	.....	.....	84.7	51.40
74 Department Store	137.00	.....	125	.....	118.00	.....	.....	.....	86.1	.....
75 Department Store	210.00	.....	275	.....	188.00	.....	5:00 p.m.	.....	89.6	.....
76 Department Store	250.00	.....	300	.....	215.00	.....	5:30 p.m.	.....	86.0	.....
77 Department Store	150.00	26.00	50	2–15	45.00	20.00	.....	.....	30.0	76.90
52 Department Store	126.00	144.00	.....	.....	126.00	62.40	4:00 p.m.	.....	100.0	43.30
63 Department Store	106.80	9.75	.....	.....	74.65	0.60	5:15 p.m.	.....	70.0	6.18
78 Hotel—	.....	430.00	.....	3–100	.....	251.00	.....	.....	.....	58.30
79 Hotel—	.....	101.00	.....	3–50	.....	68.00	.....	.....	.....	67.30
80 Hotel—	79.00	115.00	.....	3–50	47.70	80.00	.....	.....	60.5	69.50
81 Hotel—	70.00	19.30	112½	37½	64.75	21.50	.....	100.0	92.5	111.20
82 Hotel—	135.00	.....	100	.....	105.00	.....	.....	100.0	77.6	.....
83 Hotel—	.....	16.80	75	30	26.40	16.32	.....	65.0	.....	96.50
65 Hotel—	192.80	30.30	.....	.....	24.00	17.76	.....	61.2	12.5	58.70
8 Hotel—	45.00	.....	25	.....	14.00	.....	.....	.....	31.1	.....
14 Hotel— 265 Rooms	65.26	.....	Sec. Mains	.....	29.30	.....	.....	50.0	45.0	.....
15 Hotel— 155 Rooms	60.92	.....	Sec. Mains	.....	22.50	.....	.....	65.0	37.0	.....
16 Hotel— 176 Rooms	59.49	.....	Sec. Mains	.....	31.80	.....	.....	50.0	53.5	.....
17 Hotel— 150 Rooms	38.89	.....	Sec. Mains	.....	12.60	.....	.....	80.0	32.5	.....
18 Hotel— 84 Rooms	22.93	.....	Sec. Mains	.....	9.00	.....	.....	80.0	39.4	.....
19 Hotel— 250 Rooms	37.00	.....	Sec. Mains	.....	32.60	.....	.....	85.0	88.0	.....
20 Hotel—1,100 Rooms	494.50	.....	Sec. Mains	.....	184.00	.....	.....	50.0	37.4	.....
21 Hotel— 198 Rooms	76.79	.....	Sec. Mains	.....	31.60	.....	.....	60.0	41.2	.....
22 Hotel— 156 Rooms	58.87	.....	Sec. Mains	.....	17.6	.....	9:00 p.m.	65.0	29.8	.....
23 Hotel— 193 Rooms	89.94	.....	Sec. Mains	.....	11.4	.....	10:00 p.m.	31.0	12.7	.....
24 Hotel— 160 Rooms	64.68	.....	50	.....	35.2	.....	10:00 p.m.	69.0	54.5	.....
53 Hotel— 500 Rooms	182.40	267.5	.....	.....	70.8	97.6	6:00 p.m.	65.0	39.2	36.2
61 Hotel— 400 Rooms	153.50	80.0	.....	.....	34.8	28.2	.....	52.1	22.7	35.3
25 Apartments—60 Rooms	13.55	25.0	.....	.....	6.6	.....	6:30 p.m.	88.0	48.7	.....
26 Apartments—35 Rooms	24.62	.....	50	.....	15.8	.....	7:30 p.m.	86.0	64.1	.....
27 Apartments—82 Rooms	.....	.....	200	.....	30.8	.....	6:30 p.m.	39.0	.....	.....
28 Apartments—51 Rooms	17.22	.....	Sec. Mains	.....	4.4	.....	6:30 p.m.	78.0	23.4	.....
29 Apartments—55 Rooms	24.79	.....	Sec. Mains	.....	7.7	.....	6:30 p.m.	82.0	31.1	.....
30 Apartments—43 Rooms	18.80	.....	Sec. Mains	.....	7.9	.....	9:30 p.m.	70.0	42.0	.....
31 Apartments—28 Rooms	7.50	.....	Sec. Mains	.....	3.1	.....	10:00 p.m.	100.0	41.4	.....
62 Apartments—82 Rooms	30.00	40.7	.....	.....	22.9	18.0	.....	40.0	71.5	44.3
84 Apartments—	55.00	49.0	1–50	3–20	16.5	45	6:00 p.m.	65.0	30.0	91.8
85 Apartments—	241.00	.....	1–75	.....	37.0	.....	.....	.....	15.4	.....
32 Theatre—1,493 Seats	85.78	.....	Sec. Mains	.....	22.5	.....	.....	.....	26.3	.....
33 Theatre— 450 Seats	23.52	.....	Sec. Mains	.....	15.8	.....	.....	.....	67.0	.....
34 Theatre—1,200 Seats	85.50	.....	Sec. Mains	.....	41.2	.....	.....	.....	48.3	.....
35 Theatre—1,900 Seats	61.32	.....	Sec. Mains	.....	38.7	.....	.....	.....	63.3	.....
36 Theatre—1,800 Seats	173.46	.....	150	.....	91.9	.....	.....	.....	52.5	.....
37 Theatre—2,200 Seats	159.10	.....	Sec. Mains	.....	101.3	.....	.....	.....	53.6	.....
38 Theatre—3,700 Seats	428.46	.....	Sec. Mains	.....	308.0	.....	9:00 p.m.	.....	72.0	.....
39 Theatre— 800 Seats	11.55	.....	15	.....	13.2	.....	9:00 p.m.	.....	114.2	.....
40 Theatre— 500 Seats	46.50	.....	37.5	.....	22.0	.....	9:00 p.m.	.....	47.4	.....
41 Theatre— 900 Seats	36.08	.....	25.0	.....	26.4	.....	8:30 p.m.	.....	73.1	.....
42 Theatre—1,363 Seats	68.00	.....	100.0	.....	61.6	.....	9:00 p.m.	.....	90.7	.....
43 Theatre— 900 Seats	46.73	.....	50.0	.....	35.2	.....	8:00 p.m.	.....	75.5	.....
44 Theatre— 900 Seats	50.41	.....	50.0	.....	26.4	.....	9:00 p.m.	.....	52.3	.....
45 Theatre— 886 Seats	40.84	.....	25.0	.....	26.0	.....	7:30 p.m.	.....	63.8	.....
46 Theatre—1,783 Seats	154.84	.....	175.0	.....	102.1	.....	8:00 p.m.	.....	66.2	.....
47 Theatre—1,800 Seats	249.00	.....	37.5	.....	124.10	.....	8:00 p.m.	.....	49.9	.....
48 Theatre— 900 Seats	20.71	.....	50.0	.....	14.90	.....	8:00 p.m.	.....	71.9	.....
49 Theatre— 800 Seats	14.08	.....	50.0	.....	11.50	.....	7:30 p.m.	.....	81.8	.....
50 Theatre— 800 Seats	35.33	.....	37.5	.....	17.50	.....	9:00 p.m.	.....	43.4	.....
51 Theatre— 800 Seats	40.04	.....	.....	.....	17.60	.....	7:45 p.m.	.....	43.9	.....
57 Theatre—2,300 Seats	124.65	91.00	.....	.....	90.10	43.4	9:00 p.m.	.....	72.3	47.8
64 Theatre—1,600 Seats	162.00	60.00	.....	.....	70.90	26.0	7:45 p.m.	.....	43.7	16.1
93 Theatre—	324.00	123.00	200.0	3–50	200.00	126.0	.....	.....	61.7	102.3
88 Office Buildings	289.00	.....	3–100	.....	243.00	.....	.....	.....	84.0	.....
89 Office Buildings	157.00	127.00	2–100	3–50	48.00	12.3	.....	.....	30.5	9.7
90 Office Buildings	127.00	120.00	1–100	3–25	92.00	43.5	.....	.....	72.4	36.2
91 Office Buildings	170.00	41.70	50	37.5	36.00	36.8	.....	.....	21.2	88.2
92 Office Buildings	70.00	23.40	100	47.5	35.00	22.0	.....	.....	50.0	94.0
55 Office Buildings	50.10	88.00	.....	.....	46.20	19.2	4:45 p.m.	.....	90.2	21.7
59 Office Buildings	57.40	3.73	.....	.....	51.480	0.8	.....	.....	89.8	21.0
7 Cannery	.....	24.25	.....	25	.....	20.7	.....	.....	.....	86.0
60 Cannery	.....	33.70	.....	.....	.....	14.0	.....	.....	.....	41.6
94 Cannery	91.00	290.00	1–100	1–100	52.00	94.0	.....	.....	57.2	32.4
95 Cannery	.....	450.00	.....	450	.....	207.0	.....	.....	.....	46.0
96 Cannery	.....	220.00	.....	150	.....	77.0	.....	.....	.....	35.0
97 Cannery	.....	265.00	.....	225	.....	128.0	.....	.....	.....	48.3
98 Cannery	.....	293.00	.....	150	.....	109.0	.....	.....	.....	37.2
99 Cannery	.....	434.00	.....	425	.....	252.0	.....	.....	.....	58.0
54 Dairy Association	26.00	163.00	.....	.....	11.10	91.3	5:45 p.m.	.....	42.5	56.0
86 Dairy	.....	47.00	.....	3–15	.....	35.0	.....	.....	.....	74.5
87 Dairy	13.00	4.85	7.5	10.6	5.34	3.6	.....	.....	39.8	74.2
100 U. S. Army air station	.....	69.00	.....	150	.....	126.0	.....	.....	.....	183.0
101 Newspaper office	.....	61.50	.....	75	.....	60.6	.....	.....	.....	98.5
67 Newspaper	102	154.00	.....	.....	42.5	89.8	.....	.....	41.7	58.30
2 Asbestos cloth	15	450.00	.....	3–75	10.0	152.0	.....	.....	66.6	34.00
3 Welding and machine	.....	325.00	.....	250	.....	58.0	.....	.....	.....	17.80
4 Rock crusher	.....	1,757.00	.....	3–500	.....	1,294.0	.....	.....	.....	74.00
5 Walnut packing house	.....	154.50	.....	150	.....	132.5	.....	.....	.....	86.00
58 Naval repair base	61	1,093.00	.....	.....	41.5	32.2	.....	.....	68.2	2.95
6 Laundry	.....	23.00	.....	2–10	.....	18.26	.....	.....	.....	76.00
9 Ice company	.....	80.75	.....	3–25	.....	91.40	.....	.....	.....	113.10
10 Irrigation pump plant	.....	225.00	.....	225	.....	209.0	.....	.....	.....	93.00
11 Paper making mill	15	648.00	.....	600	15.0	590.0	.....	.....	100.0	91.00
12 Orange packing house	12	235.00	.....	200	12.0	178.0	.....	.....	100.0	76.00
13 Glazed tile manufacturing	11	151.00	.....	100	11.0	90.0	.....	.....	100.0	56.30
102 Store building	80	22.40	1–50	1–15	30.8	11.4	.....	.....	38.5	50.80
103 Beach club	75	145.00	1–100	3–75	37.5	76.1	.....	.....	50.0	52.30

TABLE II.

Class of Business	Installations Considered		Percent of Demand to Connected, KW.					
			Highest		Lowest		Average of all	
	Light	Power	Lights	Power	Lights	Power	Lights	Power
Hospitals	5	7	70.0	87.5	30.2	23.60	44.3	53.9
Department Stores	7	4	100.0	76.9	30.0	6.18	78.0	44.5
Hotels	18	8	92.5	111.2	12.5	35.30	44.7	66.6
Apartment Houses	9		71.5		15.4		40.8	
Theatres	23	5	114.2	102.3	23.4	16.10	62.4	60.4
Office Buildings	7	6	90.2	94.0	21.2	9.70	62.6	45.1
Canneries		8		86.0		32.40		48.0

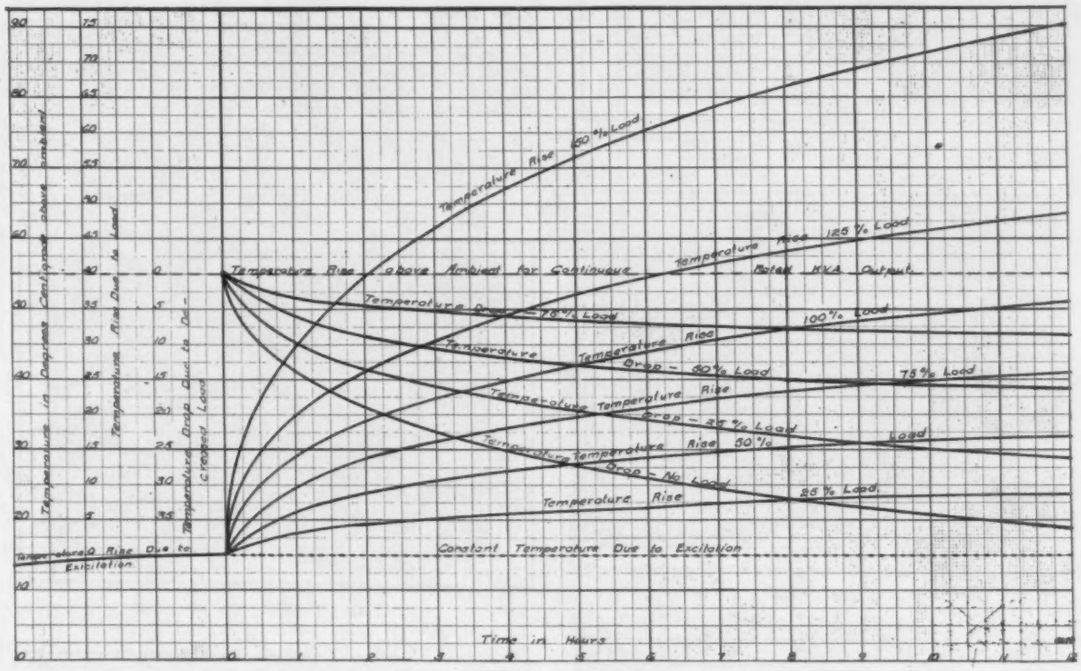

Temperature Rise 50% Load
Temperature Rise 125% Load
Temperature Rise above Ambient for Continuous Rated KVA Output
Temperature Drop - 75% Load
100% Load
Temperature Rise
Temperature Drop - 50% Load
75% Load
Temperature Rise
Temperature Drop - 25% Load
Load
Temperature Rise 50%
Temperature Drop - No Load
25% Load
Temperature Rise
Constant Temperature Due to Excitation
Temperature Rise Due to Excitation
Temperature Rise Due to Load
Temperature Drop Due to Decreased Load
Temperature in Degrees Centigrade above Ambient
Time in Hours

Fig. 2. Curve No. 1.

conditions. The written report accompanying these curves is as follows:

Distribution Transformer Capacity for Cooking and Heating Loads

The following is an outline of the methods used by the San Joaquin Light & Power Corporation to determine the transformer capacity that is necessary to serve range and water-heater loads. There are many rural installations of cooking and heating on that system which are fed from an individual transformer installation, either separately or in combination with a three-phase motor used for pumping.

Thus the problem was to learn the demands that would be encountered and to determine the size of transformer necessary for these single-residence installations as well as to determine the diversity between groups of such loads which would be encountered in the more thickly settled areas. Very little information was available several years ago when this class of load first was being served and the tendency was to install transformer capacity in excess of the actual need.

On the San Joaquin system some five or six years ago a number of load charts were obtained from existing installations in different parts of the territory. These curves were studied and an attempt made to arrive at

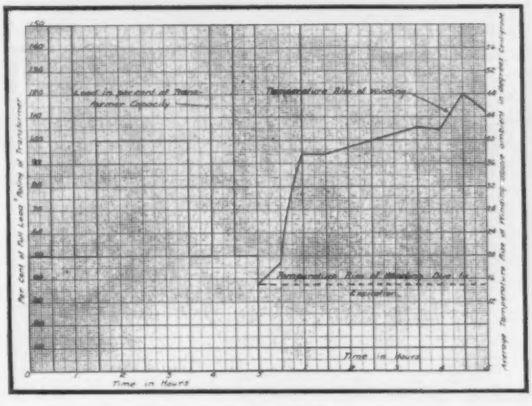

Load in per cent of Transformer Capacity
Temperature Rise at Winding
Temperature Rise at Winding Due to Excitation
Time in Hours

Fig. 3. Curve No. 2.

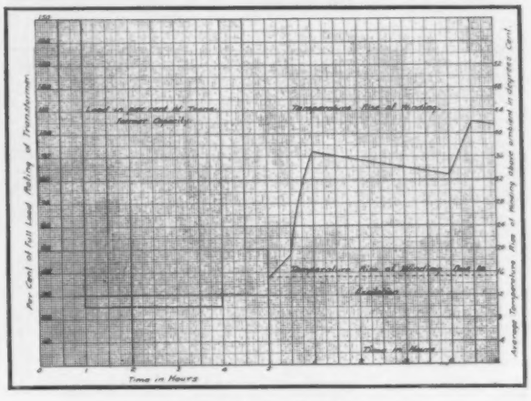


Fig. 4. Curve No. 3.

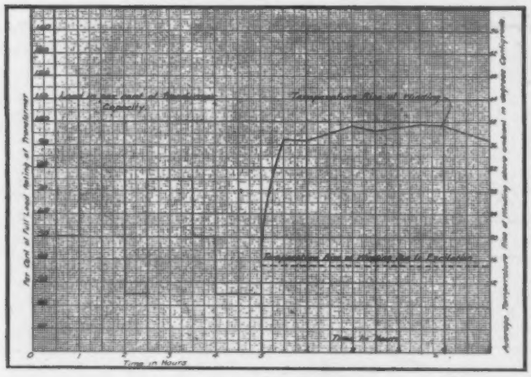


Fig. 5. Curve No. 4.

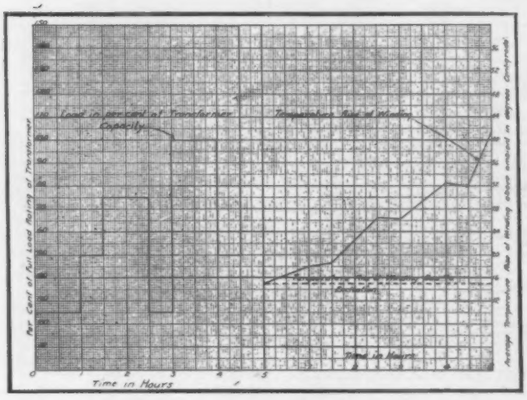


Fig. 6. Curve No. 5.

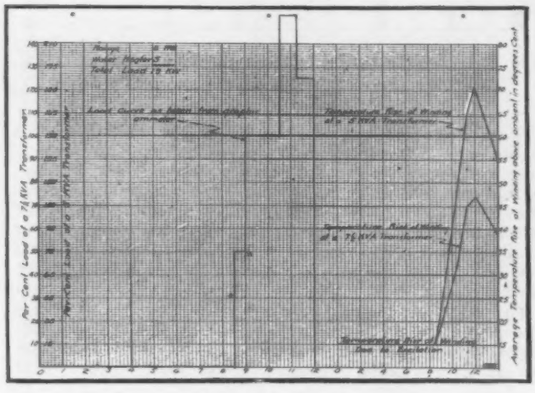


Fig. 7. Curve No. 6.

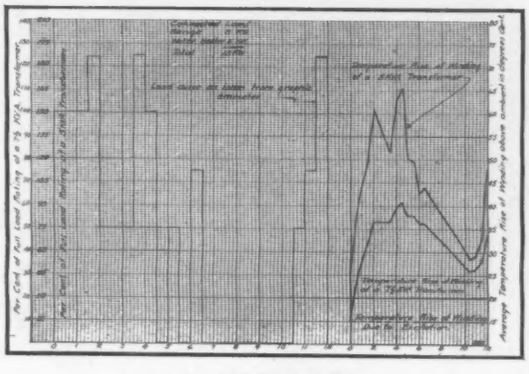


Fig. 8. Curve No. 7.

a schedule of "demand-factors" that could be used in selecting transformers. Of course great variation was noted in the use of cooking and heating equipment by different individuals. Also the type of installation affected the demand. The inclusion of much air-heating capacity tended to cause a longer sustained load while the usual chart from a range alone or a range and water-heater showed two or three short-time peaks during the 24 hours, but no great sustained load.

It is estimated that a fair measure of the transformer size required would be the average hourly demand that would occur. From the load curves mentioned above the various demands for 15 min., 30 min., one, two and three hours were determined and a general average struck. This resulted in the following tabulation of "demand factors" which were used to figure the transformer capacity required. These demand factors are the maximum hourly demands expressed in percentages of the total connected load.

Number of Consumers	Demand Factor
1	60 per cent
2 or 3	40 per cent
4 to 6	30 per cent
7 or 8	20 per cent

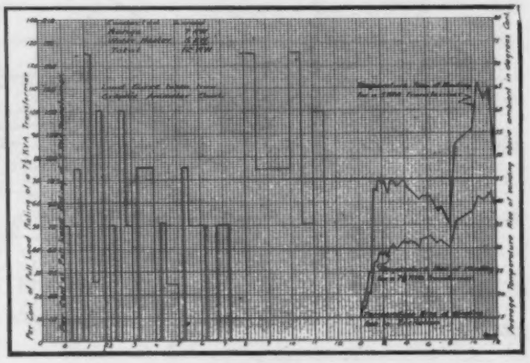


Fig. 9. Curve No. 8.

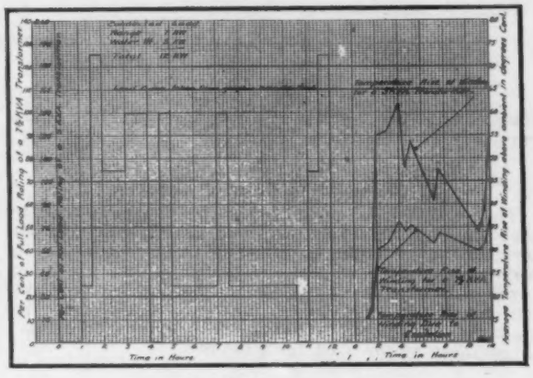


Fig. 10. Curve No. 9.

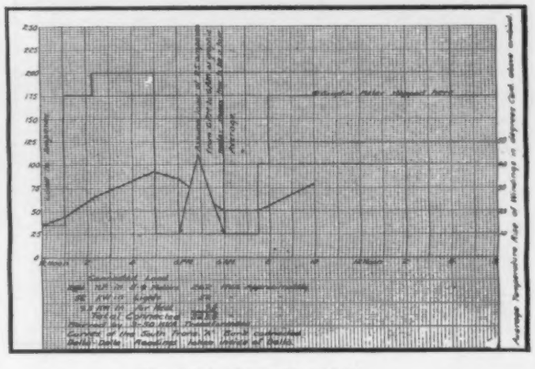


Fig. 11-A. Curve No. 10-A.

These demand factors applied to range and water-heater loads exclusively. As stated above the air-heat load was found to result in longer sustained load. Also with such load there was a higher demand for a group of installations than would occur where air heat was not included. Therefore a flat demand factor of 75 per cent was used for all air heat that was connected to the transformer installations. Later tests proved that for larger installations of air heat this factor was too high, but it seems fairly close for the smaller installations such as usually are encountered in a residence or a group of a few small installations.

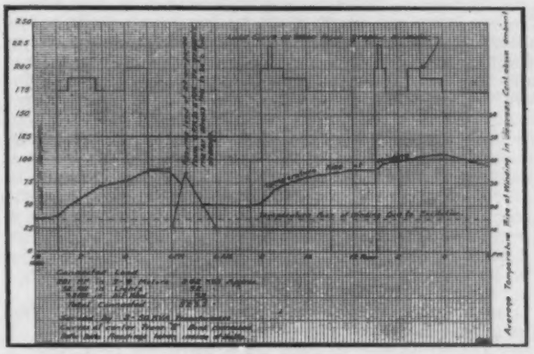


Fig. 11-B. Curve No. 10-B.

Many of the installations on the San Joaquin system consist of range, water heater and lights with about 12 to 13 kva. connected. Usually these loads are served by a 7½-kva. transformer. Two such installations served from the same transformer installation will require a 10 kva. transformer.

As it was thought that possibly too great capacity still was being installed it was decided to check the results being obtained on typical installations. Figure 2 was plotted from actual test data on distribution transformers. It shows the average temperature rise of the windings for various percentages of load and also the cooling of these windings for decreased load. The winding temperature was determined by change of resistance and therefore is the average and not the "hot-spot" temperature. Load curves then were plotted in percentages of transformer capacity and the winding temperature curve obtained.

Figures 3 to 6 inclusive are theoretical load curves which show the different effects of loads. Figure 3 has an early peak, a high sustained load and a late peak. This results in a 48-per cent rise in winding temperature. Figure 4 has the same peaks with a lower sustained load. The result is a 42-per cent rise. Figures 5 and 6 show the same consumption, the difference

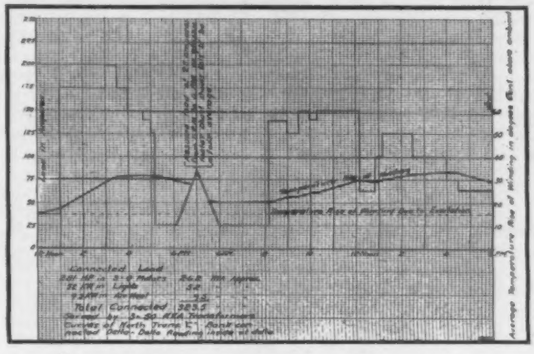


Fig. 11-C. Curve No. 10-C.

being that in 5 the peak is at the beginning of the time interval with the load gradually decreasing and in curve 6 the load gradually increases to a peak at the end of the interval. The results are respectively a 39.5-per cent rise and a 41.5-per cent rise.

Figures 7 to 10 inclusive were plotted from actual load tests taken in the field and are representative of a number that were plotted. The heat curves were plotted from Fig. 2 both for the 7½-kva. transformer installed and for a 5-kva. transformer. It may be noted that the 7½-kva. transformer is well within the rated 55-per cent temperature rise while the 5-kva. transformer exceeds this rise in each case.

Figures 1-A, 1-B and 1-C were made from an actual load test on a three-phase bank of transformers serving a combined three-phase and single-phase load. The loads plotted are for each of the three transformers in the bank. The resultant heat curves show the transformers to be well within the allowable rise.

It was found that for larger loads or groups of small loads where a low demand factor may safely be used for determining the correct transformer size from a heating standpoint, there may be short-time peaks of sufficient magnitude to cause excessive transformer regulation drop. Good voltage regulation at the appliance is very necessary for satisfactory service. Therefore it is necessary sometimes to install over-capacity in transformers to insure correct voltage. The regulation drop added to some secondary and service drop may be enough to cause dissatisfaction and complaint. The heat delivered by an appliance varies roughly as the square of the voltage at the element. Thus a comparatively small voltage drop means considerably less heat.

Figure 12 shows the approximate regulation of a 7½-kva. distribution transformer for various percentages of full load. It may be noted that for double load at 100-per cent power factor this becomes over 5 per cent. If a secondary and house wiring drop of 3 per cent were added to this the result would be 92 per cent of normal voltage at the appliance which would deliver only 80 per cent of rated heat. The transformer probably would not be damaged by such a load for a short interval, but the service certainly would not be the best.

Very much valuable information about cooking and heating loads has been obtained during the past few years, but most published data has to do with large

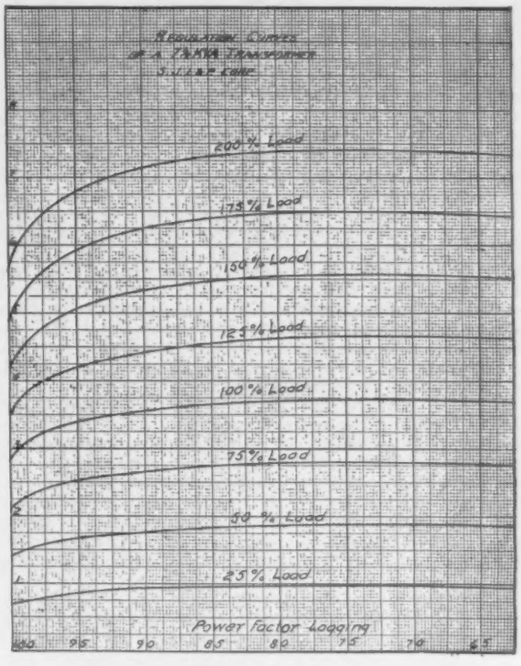


Fig. 12. Curve No. 11.

groups of such loads rather than the small installation. It would seem that there is room for more study of the demands that may be expected from the individual cooking and heating installation. This is particularly important in view of the great interest in rural electrification shown throughout the country.

Corrosion of Metals in Overhead Construction

By N. P. Carlsen, Jr.*

This subject was proposed for study in 1927 and a subcommittee was organized to make a study and report its findings. The subject was divided by the committee into three parts: (1) corrosion of conductors, its remedies and prevention; (2) corrosion of hardware, its remedies and prevention; (3) corrosion of poles and towers, its remedies and prevention.

Corrosion of Conductors

(a) Aluminum—Considerable trouble has been experienced with 7-strand A1 conductor, 266,800 circ.mil and 366,400 circ.mil, particularly in territory adjacent to San Francisco Bay. The trouble occurred at line splices and at times of failure elsewhere in the line. Upon investigation it was found that the center strand would melt and run out and at the same time burn off other outer strands, causing a failure. The cause of the splice failure was found to be due to corrosion or oxidation of the aluminum strands. It was found that the material coating the wires was almost pure hydrated oxide of aluminum. The contact resistance between contiguous strands due to the oxide film was found to be as follows:

Center to No. 1 outer	7,400 ohms
Center to No. 2 outer	5,800 ohms
Center to No. 3 outer	8,600 ohms
Center to No. 4 outer	3,000 ohms
Center to No. 5 outer	4,800 ohms
Center to No. 6 outer	2,980 ohms

From this it can be seen that the strands were practically insulated from each other. A test was run to determine what current was required to cause a failure in a piece of aluminum that was affected by oxidation and it was found that 2,000 amp. would cause the middle strand to melt and run out. The center strand is apparently heat insulated sufficiently by the oxide film or coating to cause its temperature to reach melting point before that of the outer strands. It was not possible to make the center strand of new aluminum melt before the outer strands melted.

From the results of the test we could see that a short circuit of any great magnitude would cause trouble particularly in made up splices which were nowhere near airtight or moisture proof and which were consequently more liable to permit of oxidation. Inasmuch as we had any number of made up splices in the line, we took steps to reinforce them by means of jumpers which were sewed up on each end of the old splice. One practice for aluminum joints now is compression joints A1 3-bolt clamps.

An examination of some 211,000 7-strand all-aluminum cable removed from a 60-kv. pole line in the foothills east of Marysville, originally installed about 1906, showed this same dust collected between the strands. This is the first case where this corrosion has been noticed on conductors away from the bay regions. No failures have been traced to this cause on this line, possibly because the load carried is not heavy enough or the corrosion does not exist to as great an extent as on the other lines around the bay.

Remedies—Up to the present time no satisfactory remedy has been found for this trouble and it is, therefore, deemed inadvisable to use all-aluminum conductor in territory adjacent to salt water.

(b) Aluminum Cable with Steel Core—Several cases of corrosion have been found in aluminum steel cord cable, particularly in the steel sleeve on the steel cable core of the joints in the older designs. Many joints have been examined and it has been necessary to replace many of them.

Remedies—It has been found necessary in making up joints in steel cord aluminum to coat the steel core and sleeve with some rust resisting compound. The aluminum company recommends thoroughly saturating the ends of the wire with red lead in oil before the splice is made up.

(c) Steel—Steel messenger and guy strands in the San Francisco Bay area and elsewhere where exposed to fog and salt atmosphere show an average life of from ten to fifteen years; where exposed to chemical fumes the life is substantially reduced. In the vicinity of a certain oil refinery a messenger strand and cable rings have had to be replaced three times in the past eight years.

Remedies—No remedy being obtainable for preventing the corrosion of the steel wire which is originally galvanized, it seems that it will be necessary to use some non-corrosive guy and messenger wire such as copper-clad steel. As far as the committee knows none of this has been tried and it may solve the trouble which is being experienced.

(d) Copper—An instance of trouble caused by corrosion of copper conductor occurred in 1923 on a 60-kv. pole line near Pittsburg and was caused by acid fumes from a chemical plant close to the line. Only a few spans of line carrying three 3/0 7-strand copper conductors and two No. 8 copper telephone wires were affected, but the action was so rapid that the telephone wires were practically eaten away in less than three months. As a temporary measure the new 60-kv. conductors installed were painted with an acid resisting, insulating paint which protected the conductors successfully until the escape of the fumes was stopped by the chemical company a month or so later. During that time the size of the telephone wires which were not painted was reduced from No. 8 to approximately No. 12 size.

Corrosion of Line Hardware

Considerable trouble has been experienced with hot dip galvanized iron anchor rods. In some places guy rods placed in marsh land have required replacement within from five to ten years. In other marsh lands the galvanized rods have not lasted three years. In the Imperial Valley serious corrosion is caused by the alkaline salts in the soils; 550 galvanized anchor rods had to be replaced after about twelve years' service. The Pacific Telephone and Telegraph Company is at present conducting a test on 200 samples of rods 4 ft. long and ½ in. in diameter in alkaline soils. Among these rods are different kinds of irons, steels, two copper alloys and nine different kinds of coating materials. It is planned to remove samples at three intervals of time in order that the progress of corrosion may be observed. Trouble has also been experienced with galvanized ground rods.

Considerable trouble has been experienced with line hardware such as clevices, clamps, pole steps, quarter braces, etc. Most of this trouble has been found to occur in the vicinity of the ocean or salt water bays. In some cases the hardware has only lasted from five to seven years; in others less than three years. All of the hardware which has given trouble has been hot dip galvanized.

Remedies—Several remedies have been tried among which are the following:

A protective coating to prevent the attack of alkaline salts. This consists of a pipe placed over the rod and filled with asphalt. The pipe will eventually corrode but the asphalt coating should prevent corrosion of the rod for some time. Another remedy is to paint the rods with P & P paint and wrap with tape after which another coat of P & P paint is applied. These remedies have not been in use long enough to determine their permanency. One other remedy is the use of copper clad guy rods and ground rods. These have been used for some little time and to date are in perfect condition. The only remedy for line hardware corrosion at the present time seems to be the use of stainless steel or bronze.

Corrosion of Poles and Towers

(a) Superstructure—The superstructures of steel towers are usually protected from corrosion in one of three ways—painting, sherardizing or galvanizing.

Considerable trouble has been experienced with sherardized bolts in some of the earlier tower lines. On one line in particular it has been necessary to go over the towers each year and replace bolts. The rusted bolts all have to be broken off with a chisel, only a slight tap being required.

Considerable corrosion has been observed on special towers around the San Francisco Bay area, particularly in riveted sections of galvanized towers. This is due to the riveted sections being put together prior to galvanizing. The corrosion takes place between plates in the riveted section and the oxide runs out and over the galvanizing. It has been necessary to paint all riveted

* Report of subcommittee of overhead system committee—N. P. Carlsen, Jr., chairman. A. S. Glasgow, W. T. Hannum, G. E. Honn, H. N. Kalb, S. W. Kephart, E. Y. Porter, G. A. Riley, D. D. Smalley, L. B. Smith, E. R. Stauffacher, A. E. Strong.

sections but this has not proved altogether effective. It is proposed to either weld or bolt all new work in order to overcome this defect.

The anchor towers and the high towers carrying lines across the Carquinez Straits were among the earliest erected on the Pacific Gas and Electric Company system, and on account of their location adjacent to the bay and to a nearby smelter have been subjected to conditions conducive to corrosion. They have been repainted three times. Other special high towers around the bay erected between 1912 and 1915 are now being repainted for the second time. Until 1926 all painting was done by hand after cleaning the steel by hand with wire brushes. This work is now being done by compressed air. The steel is clean of all rust and loose paint by the sand blasting method. Much better work can be done by this method because the sand will clean all corners which could not be reached very well with hand brushes, as well as it cleans flat surfaces. Given sufficient work to cover the cost of the outfit, the mechanical work is also cheaper than hand work. After the steel is cleaned two coats of graphite paint are put on with spray guns. It is hoped that this treatment will protect the steel from corrosion for approximately 15 years under the severe weather conditions existing around the bay and for a considerably longer period in more favorable locations.

Recently a serious case of corrosion was discovered on four special towers crossing San Francisco Bay. This corrosion took place on steel members encased in concrete. The concrete was 3 in. thick and entirely covered the members. It is not known whether the members were painted prior to concreting, but salt water concrete was used. At the present time the concrete is being forced off due to the corrosion and the under side of several of the members is exposed. It is intended to strip off the old salt water concrete, then chip and sand blast the steel, after which it will be coated with biturine enamel. In all probability the concrete will not be replaced, its only use being protection for the steel.

The standard foundation for most of the Pacific Gas and Electric Company towers consists of an angle iron placed in a reinforced concrete pier. The upper end of the angle iron is galvanized d o w n to approximately 1 ft. below the top of the concrete. A great many of these footing angles show rust at the concrete line in two or three years after installation, especially in hilly or cultivated country, or where alkali soils are found. This corrosion is evidently caused by dirt or dust and moisture accummulating on the top of the concrete around the galvanized angle. On all cases found further corrosion has been stopped by painting the portions of the steel affected. It is now the practice on all new work to paint the steel about 6 in. above and below the concrete line with biturine primer followed by a hot application of biturine enamel. Care is also taken to see that the top of the concrete is sufficiently rounded to drain off any moisture that may collect.

The towers above mentioned all have concrete footings. Two companies using earth footings report some corrision particularly in alkaline soils. One company reports that out of a total of 1,863 towers inspected which had earth footings 49 towers were found to be rusting below the ground line; 126 of the tower footings were recommended for painting.

Remedies—One remedy being used is to treat the affected surface with a water emulsion of asphaltum. This is applied with a brush after thoroughly cleaning the rusted parts. Another remedy has been the use of zinc rods connected with copper conductors to the base of the towers. This remedy seems to be quite satisfactory from the standpoint of arresting further corrosion of the tower footings. One company is using this remedy as common practice.

Conclusions in General

As long as the elements necessary to life (oxygen and moisture) remain in our atmosphere and the use of iron and steel continue, the subject of corrosion will be an important one. This subject is becoming more vital every year as the uses and adaptations of steel increase. Practically every power company has reported on some trouble it has been having due to corrosion and experience indicates that as time goes on further trouble will be had.

The rusting of iron and steel is very well described by Bablik as follows:

> When the metal is exposed to atmospheric influences it becomes coated with a film of moisture, which is formed, even in dry weather, whenever changes of temperature result in the atmosphere becoming supersaturated with water-vapor. Under these conditions the iron is in contact with an electrolyte, ions passing into solution therein, as in the case of any other metal, until the osmotic pressure of the ions is equal to the solution pressure. In the case of iron, however, the atmospheric oxygen prevents the attainment of this state of equilibrium, since it oxidizes the Fe++ ions and continuously removes it out of solution, in the form of insoluble hydroxide, so that it can never attain, in the solution, the degree of concentration corresponding to the solution pressure. So long as water and oxygen are present, the process continues, and is assisted by local currents set up as the result of the heterogeneous composition of the iron; the iron rusts, and the rust eats its way further in.

It is obvious then that the best method of preventing rust is to seal the material and keep it from contact with the elements. This can be accomplished by painting, sherardizing, electro-galvanizing, hot dip galvanizing, Schoop spraying, and cadmium coating which is now coming into the field. Although none of these give entire protection for the life of the iron or steel, hot dip galvanizing is by far the most successful as it gives a double protection. First, the steel is hermetically sealed from the corrosive agents and secondly, due to iron and zinc being a galvanic couple even though small areas of the steel are exposed, the steel is protected at the expense of the zinc, this latter metal being the electro positive to iron.

ing, sherardizing, electro-galvanizing, hot dip galvanizing is the best for many reasons. When a bar of steel is immersed in the zinc bath, after pickling and fluxing, the bar is heated and its pores expanded. The molten zinc enters the open pores making an exceptionally good bond between the steel and the zinc. After emerging from the bath the molten zinc rapidly cools and in setting contracts to make a tight waterproof coating. In the galvanizing of structural shapes it is not practical to wipe the members which insures a good heavy coat. We then have in the hot dip process a heavy coat of zinc which is impervious to the elements with an exceptionally good bond. This is not true with the other three zincing processes, as the coating is much lighter and does not hermetically seal the member to which the coating is applied.

The most important features in the galvanizing of iron or steel are the use of virgin spelter in the bath; the proper temperature of the molten zinc, the correct time for the material to remain in the bath; and the proper handling after removal from the bath to give a smooth even coating—the use of drops of zinc on the edges of material is of no value and is even a detriment as they will be broken off in handling leaving a spot thinner than the rest of the coating.

The galvanizing riveted work after assembly is practical to some extent. There is no question as to the effectiveness of this method being greater than that of a painted job. However, we know from taking these members apart after galvanizing that the zinc does not coat the portion of the members held in contact by the rivets. The acid from the pickling bath does penetrate into these places destroying the mill scale and starts rusting. Attention is usually attracted to these points by stain on galvanized coating washed down by the rain. Where such members are in use they should be watched and the questionable parts painted at intervals. The best practice would undoubtedly be to galvanize the parts separately and assemble them with galvanized bolts. This could be done in most instances.

In conclusion, it must be remembered that nothing has yet been discovered that will protect iron or steel for an indefinite period, but that hot dip galvanizing does give the best protection known. It also must be borne in mind that the same quality of coating will vary in its effectiveness and length of life according to the climatic conditions in which it is placed.

Pole-Line Structures, Devices and Maintenance*

This committee has made a study of the following eight subjects which were suggested at the fall meeting in Los Angeles:

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* Report of subcommittee of overhead systems committee.—H. H. Buell, J. E. Crilly, R. E. Cunningham, F. E. Dellinger, C. A. P. Duffie, Fred Garrison, F. J. Gleis, H. F. Hartzell, J. F. Hodges, B. C. Holst, H. N. Kalb, F. H. Klippel, C. W. Lightner, G. A. MacDonald, E. A. McGinty, E. Y. Porter, Howard Pratt, A. J. Theis.

1. Methods used to prevent grass fires from burning poles.
2. Use of solderless connectors.
3. Maintenance of distribution transformers and devices.
4. Bakelite tubes vs. porcelain tubes for 11 and 16-kv. fuses.
5. Painted vs. unpainted crossarms.
6. Methods of stubbing poles.
7. Tree trimming methods and procedure.
8. Wooden vs. steel poles for distribution work.

Method Used to Prevent Grass Fires From Burning Poles

The practice of cleaning vegetation around transmission and distribution poles is the method most generally followed by practically all companies in the state to prevent grass fires from burning the poles. Out of eight companies interviewed, eight make a practice of cleaning around transmission poles. On distribution lines from 33 kv. down to 11 kv., the practice of cleaning vegetation around poles is practiced by some of the companies in areas covered by heavy weeds or brush growth. So far as our investigation has gone we have not found any company making a practice of using weed eradicator for this purpose. The United States

Fig. 1. View of an area after being swept by severe brush fire. Telephone line on untreated poles, power line on pressure-treated poles. Telephone line was protected by local fire department.

Forestry Service in some instances uses torches for burning brush and cleaning fire breaks, but this method does not seem to prevail among the power companies. The area cleared necessary to prevent poles from igniting from grass or brush fires varies from 3 to 20 ft. depending on the density and character of the vegetation. There does not seem to be any standard in this connection except with the State Highway Commission, which specifies in its permits that a radius of 10 ft. must be kept clear of vegetation.

Some experimenting has been done with chemical weed eradicator, but sufficient time has not elapsed to draw any definite conclusion as to the results which may be expected. The ground around a number of poles was treated with a solution of calcium chloride. This was applied in May, 1927. On an inspection which was made in February, 1928, no vegitation had appeared in the area treated. In making this experiment approximately three quarts of solution per square yard of area was used. The cost in carload lots is approximately 8½ cents per gallon.

The fire resisting qualities of poles treated with creosote under pressure is one that appears to have some possibilities. On two occasions brush fires have swept through an area where pressure treated poles were set and in close proximity to this line was a line of poles that were butt treated only. In one case the poles that were not treated were destroyed, while in the other case the fire department by using considerable water, saved the poles that were not treated, while the poles that were pressure treated did not require any

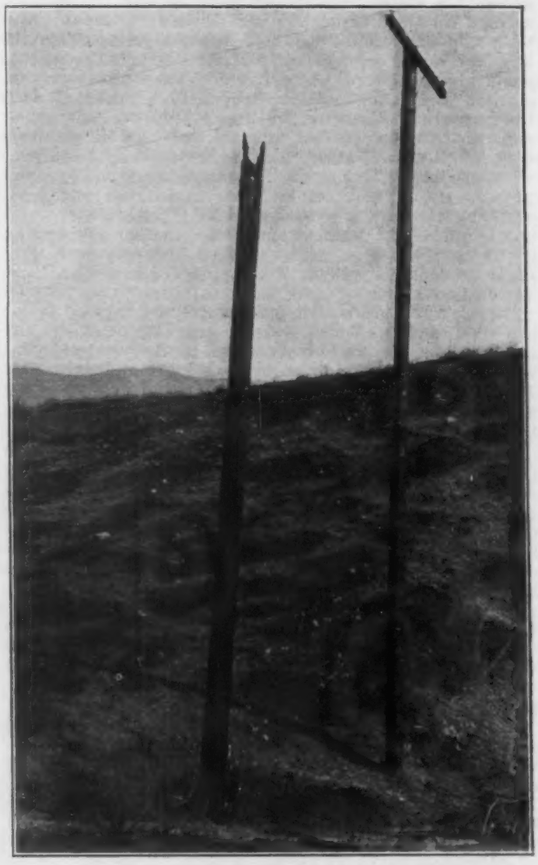


Fig. 2. Fire-swept poles. The badly burned pole was untreated, while the power-line pole was pressure-treated.

TABLE I—Data on Idyllwild Line.

Physical Data

Length of line (on steel poles)	7.193 Miles
Voltage	33 kv. Delta
Configuration and spacing	Flat horizontal 4 ft. 6 in. between phases; on extra long spans 9 ft. 0 in. between phases
Guys to anchor (inc. 1 guy to large tree)	47
Normal steel pole, latticed, all parts galvanized and bolted:	
Length over all	40 ft. 0 in.
Top	15 x 15 in.
Ground line (6 ft. from bottom)	24 x 24 in.
Bottom	8 x 8 in.
Crossarm	3 in. pipe, 9 ft. 6 in.
Total number steel structures	98
Two-pole structures (2 Std. 40-ft. poles, Spec. 18 ft. 6 in. pipe D. A.)	6
Single-pole structures	92
Std. 40-ft. pole units—total used	104
5-ft. base extensions (45-ft. poles)	4
10 ft. base extensions (50-ft. poles)	4
Transposition top extensions	8
Single 9 ft. 6 in. steel pipe crossarms	82
Double 9 ft. 6 in. steel pipe crossarms	12
Double 18 ft. 6 in. steel pipe crossarms on 2-pole structure	6
Average span	380 ft.

Cost Data

Average cost of 40-ft. standard steel pole units laid down at Hemet	$66.40 each

Construction Costs	Total	Per Pole (104)	Per Mile (7.193)
Brushing and clearing R/W	$ 1,282.44	$ 12.33	$ 178.20
Digging holes, poles and guys	1,292.72	12.43	179.50
Hauling and assembling	1,998.99	19.22	278.00
Setting and guying	1,214.85	11.71	168.20
Eng. and Misc. prorated	369.50	3.55	51.30
Total labor and Eng.	6,158.50	59.24	855.20
Material, pole struc. only	6,905.60	66.40	961.00
Total direct charges	$13,064.10	$125.64	$1,816.20

For comparison, the 2.3-kv. wood-pole lines built at same time in same general vicinity, consisting of 35-ft. and 40-ft. butt-treated cedar poles, average span 215 ft., cost per pole $47.80; per mile $1,170.00.

TABLE II—Strength tests of creosoted fir poles.

Pole No.	Length	Diameter Top	Diameter Bottom	Diameter Ground Line	Length of Butt Below Ground Line	Load at Top	Deflection	Modulus of Rupture	Distance from Top Load to Break	Distance from Top Load to Ground Line
1	70 ft.	9½ in.	14¾ in.	13⅝ in.	8 ft.	650 800 1,100 1,250 1,430 2,875	1 ft. 4 in. 2 ft. 6 in. 3 ft. 9 in. 5 ft. 2 in. 6 ft. 10 in. 17 ft. 8 in.	9,049	55 ft. 6 in.	61 ft. 6 in.
2	70 ft.	9½ in.	15¾ in.	13½ in.	8 ft.	400 550 820 1,100 1,260 2,550	1 ft. 0 in. 2 ft. 1 in. 3 ft. 8 in. 5 ft. 0 in. 6 ft. 0 in. 16 ft. 0 in.	8,058	61 ft. 9 in.	61 ft. 9 in.
3	70 ft.	9½ in.	13½ in.	13 in.	8 ft.	350 500 600 750 890 1,050 2,240	1 ft. 0 in. 2 ft. 2 in. 3 ft. 2 in. 4 ft. 3 in. 5 ft. 2 in. 6 ft. 1 in. 17 ft. 0 in.	7,678	56 ft. 0 in.	61 ft. 6 in.
*4	70 ft.	8⅝ in.	13½ in.	13¼ in.	8 ft.	240 450 550 700 840 990 2,040	1 ft. 5 in. 2 ft. 3 in. 3 ft. 1 in. 4 ft. 1 in. 5 ft. 0 in. 6 ft. 0 in. 18 ft. 0 in.	6,595	58 ft. 7 in.	61 ft. 5 in.
*4A	70 ft.	8⅛ in.	13½ in.	12⅝ in.	8 ft.	600 700 800 900 1,100 2,100	2 ft. 0 in. 3 ft. 0 in. 4 ft. 2 in. 5 ft. 4 in. 6 ft. 0 in. 13 ft. 6 in.	8,097	31 ft. 0 in.	61 ft. 6 in.
5	65 ft.	8⅝ in.	13⅝ in.	11⅞ in.	8 ft.	300 700 1,050 1,300 2,300	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 16 ft. 0 in.	9,418	47 ft. 8 in.	56 ft. 0 in.
*6	65 ft.	8 · in.	13⅝ in.	12½ in.	8 ft.	450 850 1,300 1,700 3,000	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 16 ft. 0 in.	10,627	41 ft. 4 in.	56 ft. 6 in.
*7	65 ft.	8¾ in.	13¼ in.	12¾ in.	8 ft.	500 900 1,250 1,600 2,300	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 14 ft. 0 in.	7,677	41 ft. 0 in.	56 ft. 6 in.
8	65 ft.	8½ in.	12⅝ in.	12⅛ in.	8 ft.	500 850 1,200 1,600 3,000	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 16 ft. 0 in.	11,746	37 ft. 8 in.	57 ft. 0 in.
*9	65 ft.	7¾ in.	13 in.	11¾ in.	8 ft.	500 900 1,100 1,500 2,100	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 14 ft. 0 in.	8,969	49 ft. 6 in.	56 ft. 7 in.
10	60 ft.	8½ in.	12¾ in.	12¼ in.	7 ft. 6 in.	300 500 800 930 1,180 2,440	1 ft. 0 in. 2 ft. 2 in. 3 ft. 5 in. 4 ft. 1 in. 5 ft. 2 in. 13 ft. 1 in.	8,452	49 ft. 0 in.	52 ft. 0 in
11	60 ft.	8⅛ in.	11¾ in.	11¾ in.	7 ft. 6 in.	220 550 820 1,150 2,500	1 ft. 0 in. 3 ft. 2 in. 5 ft. 1 in. 7 ft. 3 in. 17 ft. 0 in.	9,844	42 ft. 5 in.	52 ft. 2 in.
12	60 ft.	8⅛ in.	12⅛ in.	10¾ in.	7 ft. 6 in.	480 750 1,100 1,410 2,380	2 ft. 4 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 14 ft. 0 in.	11,964	48 ft. 7 in.	51 ft. 0 in
13	60 ft.	8¼ in.	12⅝ in.	12⅛ in.	7 ft. 6 in.	450 810 1,200 1,600 2,250	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 13 ft. 2 in.	8,063	52 ft. 2 in.	52 ft. 2 in.
14	60 ft.	8¼ in.	11⅝ in.	11⅛ in.	7 ft. 6 in.	450 800 1,200 1,600 2,000	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 12 ft. 0 in.	9,249	46 ft. 0 in.	52 ft. 0 in.
15	50 ft.	8 in.	11⅝ in.	10¾ in.	7 ft. 6 in.	400 650 930 1,250 2,500	1 ft. 3 in. 2 ft. 2 in. 3 ft. 0 in. 4 ft. 2 in. 10 ft. 0 in.	11,490	41 ft. 11 in.	41 ft. 11 in.
16	50 ft.	8¼ in.	12¼ in.	11½ in.	7 ft. 6 in.	750 1,300 1,800 2,200 2,550	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 10 ft. 0 in. 12 ft. 0 in.	8,571	38 ft. 0 in.	41 ft. 9 in.

*Ground line diameter on these poles is slightly greater than one and one-half times the top diameter, but the actual ground line diameter was used in calculating modulus of rupture in all cases.

TABLE II—Strength tests of creosoted fir poles.

Pole No.	Length	Diameter Top	Diameter Bottom	Diameter Ground Line	Length of Butt Below Ground Line	Load at Top	Deflection	Modulus of Rupture	Distance from Top Load to Break	Distance from Top Load to Ground Line
17	50 ft.	8¼ in.	11⅜ in.	11⅛ in.	7 ft. 6 in.	550 1,100 1,550 2,050 3,000	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 14 ft. 0 in.	11,339	41 ft. 0 in.	42 ft. 6 in.
18	50 ft.	8⅛ in.	11⅜ in.	11 in.	7 ft. 6 in.	600 1,200 1,700 2,300 2,850	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 10 ft. 0 in.	11,034	41 ft. 1 in.	42 ft. 1 in.
19	50 ft.	8 in.	11 in.	10½ in.	7 ft. 6 in.	550 1,100 1,450 1,800 2,000	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 10 ft. 0 in.	8,814	38 ft. 0 in.	41 ft. 8 in.
20	40 ft.	8⅜ in.	10½ in.	10½ in.	7 ft. 0 in.	500 900 1,350 1,700 2,400	1 ft. 0 in. 2 ft. 0 in. 3 ft. 0 in. 4 ft. 0 in. 7 ft. 2 in.	8,166	32 ft. 2 in.	32 ft. 2 in.
21	40 ft.	8 in.	11½ in.	11 in.	7 ft. 0 in.	1,200 2,000 2,700	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in.	8,073	31 ft. 0 in.	32 ft. 6 in.
22	40 ft.	8 in.	10⅝ in.	10 in.	7 ft. 0 in.	800 1,300 2,020 2,700	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 10 ft. 0 in.	10,910	29 ft. 6 in.	33 ft. 0 in.
23	40 ft.	8¼ in.	12 in.	11⅛ in.	7 ft. 0 in.	1,100 2,150 2,750 3,050	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in.	8,905	30 ft. 8 in.	32 ft. 10 in.
24	40 ft.	8 in.	11¼ in.	10 in.	7 ft. 0 in.	1,080 1,620 2,330 2,750	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 10 ft. 0 in.	10,916	29 ft. 8 in.	32 ft. 5 in.
25	35 ft.	7¼ in.	9⅞ in.	8¾ in.	6 ft. 0 in.	600 800 1,150 1,500 2,050	1 ft. 1 in. 2 ft. 1 in. 2 ft. 11 in. 4 ft. 0 in. 5 ft. 10 in.	10,679	26 ft. 0 in.	28 ft. 6 in
26	35 ft.	7⅞ in.	10½ in.	9¾ in.	6 ft. 0 in.	1,070 1,900 2,470 2,600	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in.	9,732	26 ft. 0 in.	28 ft. 4 in.
27	35 ft.	7½ in.	9½ in.	9 in.	6 ft. 0 in.	1,050 1,850 2,600 2,800	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in.	13,169	28 ft. 0 in.	28 ft. 0 in.
28	35 ft.	7 in.	9½ in.	8½ in.	6 ft. 0 in.	980 1,550 2,150 2,400	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in.	13,399	20 ft. 6 in.	28 ft. 0 in.
29	35 ft.	7½ in.	10¼ in.	9⅝ in.	6 ft. 0 in.	1,050 2,150 2,750	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in.	10,763	23 ft. 3 in.	28 ft. 6 in.
30	55 ft.	8⅛ in.	12 in.	11½ in.	7 ft. 6 in.	600 1,075 1,500 1,950 2,500	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 14 ft. 0 in.	9,477	44 ft. 0 in.	47 ft. 1 in.
31	55 ft.	8 in.	12 in.	11⅜ in.	7 ft. 6 in.	500 800 1,300 1,675 2,650	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 14 ft. 0 in.	10,344	37 ft. 3 in.	46 ft. 11 in.
32	55 ft.	8 in.	11¾ in.	11⅛ in.	7 ft. 6 in.	500 900 1,200 1,600 2,400	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 12 ft. 0 in.	10,014	35 ft. 0 in.	46 ft. 11 in.
33	55 ft.	8¼ in.	11½ in.	10⅞ in.	7 ft. 6 in.	450 875 1,150 1,700 2,640	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 14 ft. 0 in.	11,771	40 ft. 10 in.	46 ft. 10 in.
34	55 ft.	8 in.	12 in.	11 in.	7 ft. 6 in.	550 920 1,350 1,700 2,100	2 ft. 0 in. 4 ft. 0 in. 6 ft. 0 in. 8 ft. 0 in. 12 ft. 0 in.	10,488	43 ft. 6 in.	47 ft. 6 in.

attention and were not damaged. In Fig. 1 the line on the right-hand side of the picture was built of pressure treated poles while the line on the left side was butt treated early. The butt treated poles, as stated before, were saved from destruction by the fire department. In Fig. 2 the pole that shows damage was not treated while the other pole was full treated and withstood the fire without any damage. Fig. 3 shows the condition of the full treated poles after the fire had gone through.

Use of Solderless Connectors

The use of solderless connectors does not seem to be general, although a number of companies are using them, while others are experimenting at the present time. These connectors are made and are being used on wire sizes from No. 8 to 4/0, although the majority have been used on No. 6, 4 and 2. The solderless connector has been used on practically all voltages up to and including 33 kv. The telephone companies are interested in this type of connector as it saves soldering and insures good connection. Development work along this line is being done to build a type of connector for use on switchboard work which will eliminate heavy lugs and soldering. Some experimental work has also been done in developing a clamp of this type for aluminum conductors. The fact that satisfactory connections can be made on hard drawn copper, without soldering, is of a great advantage.

Maintenance of Distribution Transformers and Their Devices

There seems to be a wide variation in the method followed by different companies in the maintenance of their distribution transformers. However, the operating companies seem to be pretty well agreed that distribution transformers should be inspected once every two or three years to determine the condition of the oil, hangers, bushings, leads, etc. This work is generally done by a special crew, equipped to make minor

repairs on the job, when trouble is found upon inspection. If extensive repairs are needed, such as cleaning sludge from windings and cases, the transformers are returned to shop or storeroom to be taken care of. Considerable trouble has been experienced in some locations where the systems have been cut from 2,300 volts to 4,000 volts, due to the very small primary bushings in some of the older type transformers. When these bushings become dirty, there has been enough leakage to burn off the leads or cause pole fires which have interrupted service. The transformer cases are of such design that larger bushings cannot be installed and when this trouble has occurred in some instances the bushings have been taken out and lead cables run from the primary cut-out through the transformer bushing hole and the lead cable sealed, in the case. This, of course, makes a temporary job only, but will last as long as the transformer is in service at that particular location.

Considerable argument has arisen as to the proper procedure when distribution transformers are removed from service. In some cases it has been the rule that all transformers removed from service and returned to the general store were to be put through the shop and test departments for cleaning, replacing bushings, or leads where necessary. This was a considerable item of expense and after giving the matter careful study it was decided to make an inspection of the transformer when it was removed and if this inspection did not reveal any defects or any indications that the coils were badly sludged, the transformer would be returned to service without going through the shop, the assumption being that if the transformer was working satisfactorily when removed and did not show any signs of distress on inspection, it would in all probability return to service without any trouble. This procedure has saved considerable maintenance money and has cause very little trouble.

The question as to whether transformer cases should be grounded on voltage above 6,600 brings out the fact that the power companies are nearly equally divided on this subject. Grounding the transformer cases is believed by some operating companies to be a protection to linemen, although this is not the opinion of all parties questioned. If the transformer cases are not grounded the potential across the bushings is very much reduced and less trouble from leaky bushings occurs. Removal of ground from transformer cases by one company operating in the south has reduced very materially the trouble caused by lightning. Formerly during severe lightning storms a great many transformers were lost where the cases were grounded, but since removing the grounds this loss has been almost nil. The subject of transformer fuses is one that always calls forth considerable discussion. Several companies are developing or have developed recently new types of fuses, but to date we have nothing authentic to suggest.

Bakelite Tubes vs. Porcelain Tubes for 11 and 15-kv. Fuses

As stated before in the discussion of line transformers and devices, the subject of fusing transformers is one which is always open for discussion. In the work of this committee the fact was brought out that bakelite will stand the weather reasonably well, but will not stand an arc for any appreciable time. Horn fiber when dry will stand an arc better, but absorbs moisture more readily than bakelite. A great many cases have been reported where the bakelite fuses have blown after which the current continues to creep over the outside of the fiber tubes until a ziz-zag path is formed which has become carbonized. The tubes will then soon burn off and the burning particles fall to the ground and start grass fires which have been rather expensive in some instances. The advantage of the bakelite or horn fiber tubes is the fact that there is practically no breakage in handling and the tubes can readily be refused if they are not damaged by the blowing of the fuse. The reports from the majority of the companies interviewed who use the bakelite tubes, indicate that they have considerable trouble with the tubes burning during wet weather.

This trouble is eliminated entirely when the porcelain tubes are used; the only objection which has been presented against the porcelain tubes is the fact that in some instances the tubes explode when the fuses are blown. A number of the companies return their tubes to shop for refilling as it does not seem practical to attempt to refill in the field, particularly if powder is used to smother the arc. Tubes that are refilled in the field are very apt to cause trouble on account of the wire being run through the tube with no provision made to smother the arc when the fuse blows the next time. Some considerable trouble has been experienced with the aluminum fuse wire due to the fuse corroding and breaking under practically no load.

Painted vs. Unpainted Crossarms

The practice of using painted crossarms seems to be quite general among the power companies, particularly in the urban territory. One company has adopted the

Fig. 3. A close-up of one of the pressure-treated poles shortly after passage of severe brush fire. Pole is not damaged.

standard creosote treated crossarms and has found this method to be very satisfactory although the practice has only been in use for approximately a year. The crossarms are dipped in creosote by the manufacturer and shipped to the user in this condition. Where painted crossarms are used it is the general practice to brush the paint on, although one company uses spray guns for painting. The cost for painting varies from 5½ cents per arm to 52 cents per arm and from the information gathered it would appear that the arms would have to be painted once every seven to ten years if yellow paint is used to comply with General Order No. 64.

A number of companies are using high-voltage signs instead of repainting the arms after the paint has faded to such an extent that it does not comply with the railroad commission order. The advantages of the full treated arms are, first, protection against the weather as the penetration appears to be fully equal to the penetration obtained by paint; second, the protection against termite attack; and third, that it is not necessary to repaint or retreat the arms after they have once been treated.

Method of Stubbing Poles—Patent Equipment vs. Bolting and Wrapping

There is quite a variation in the attitude of utility companies using pole lines as to the advisability of stubbing poles except as an emergency measure. However, our investigation brings out the fact that the practice is quite generally followed in rural territory or where slow growing load has to be taken care of. It would appear that considerable money could be saved if more of this work were done on poles which are in good condition above the ground line. If the proper stubbing job can be done for $10 or $15 it is possible to get from ten to fifteen years' additional life out of

TABLE III—Weight and deflection of fluted steel poles.

Top Diam. Inches	Bottom Diam. Inches	Type	Pole Weight	Deflection in Inches with Load Applied 2 Ft. Below Top: 100 Lb.	200 Lb.	400 Lb.	600 Lb.	800 Lb.	1,000 Lb.	1,500 Lb.	2,000 Lb.	2,500 Lb.	3,000 Lb.	Ultimate Transverse Load Applied 2 Ft. From Top
Height 22 ft. Above Ground Line														
5.90	10.85	Standard	405	0.45	0.90	1.80	2.70	3.60	4.51	6.27	....	....	....	3,490 lb.
5.90	10.85	Extra heavy	619	0.27	0.55	1.09	1.64	2.19	2.73	4.10	5.47	6.34	....	5,770 lb.
5.90	10.85	Double extra heavy	799	0.21	0.43	0.86	1.29	1.72	2.15	3.22	4.29	5.37	6.43	7,330 lb.
6.80	11.75	Standard	458	0.33	0.66	1.33	1.99	2.65	3.31	4.97	6.62	....	....	4,030 lb.
6.80	11.75	Extra heavy	695	0.20	0.40	0.81	1.21	1.61	2.01	3.01	4.01	5.02	6.02	6,470 lb.
6.80	11.75	Double extra heavy	895	0.16	0.32	0.63	0.95	1.26	1.58	2.37	3.15	3.94	4.73	8,490 lb.
Height 24 ft. Above Ground Line														
5.45	10.85	Standard	445	0.65	1.30	2.60	3.90	5.20	6.50	....	....	....	....	3,180 lb.
5.45	10.85	Extra heavy	698	0.40	0.79	1.58	2.36	3.15	3.94	5.90	....	....	....	5,240 lb.
5.45	10.85	Double extra heavy	903	0.31	0.62	1.24	1.86	2.48	3.09	4.63	6.18	....	....	6,680 lb.
6.35	11.75	Standard	473	0.48	0.96	1.92	2.87	3.83	4.78	7.18	....	....	....	3,750 lb.
6.35	11.75	Extra heavy	729	0.29	0.58	1.16	1.74	2.32	2.90	4.35	5.80	....	....	6,180 lb.
6.35	11.75	Double extra heavy	947	0.23	0.47	0.92	1.37	1.83	2.28	3.42	4.57	5.70	....	7,870 lb.
7.70	13.10	Standard	560	0.30	0.60	1.19	1.78	2.37	2.96	4.45	5.93	....	....	4,580 lb.
7.70	13.10	Extra heavy	850	0.18	0.36	0.72	1.08	1.44	1.80	2.70	3.49	4.49	5.38	7,550 lb.
7.70	13.10	Double extra heavy	1,095	0.14	0.28	0.57	0.85	1.13	1.41	2.12	2.83	3.53	4.24	9,610 lb.
Height 26 ft. Above Ground Line														
5.90	11.75	Standard	490	0.66	1.32	2.63	3.94	5.25	6.57	....	....	....	....	3,430 lb.
5.90	11.75	Extra heavy	761	0.40	0.80	1.60	2.40	3.19	3.98	5.98	....	....	....	5,680 lb.
5.90	11.75	Double extra heavy	996	0.31	0.63	1.25	1.88	2.50	3.13	4.69	6.26	....	....	7,240 lb.
7.25	13.10	Standard	581	0.41	0.81	1.63	2.45	3.26	4.08	6.12	....	....	....	4,190 lb.
7.25	13.10	Extra heavy	894	0.25	0.49	0.99	1.48	1.98	2.48	3.71	4.95	6.18	....	6,920 lb.
7.25	13.10	Double extra heavy	1,166	0.19	0.39	0.78	1.17	1.56	1.95	2.92	3.90	4.87	5.84	8,800 lb.
Height 28 ft. Above Ground Line														
5.45	11.75	Standard	505	0.89	1.78	3.56	5.35	7.12	....	....	....	....	....	3,160 lb.
5.45	11.75	Extra heavy	792	0.54	1.08	2.16	3.24	4.31	5.39	8.08	....	....	....	5,210 lb.
5.45	11.75	Double extra heavy	1,034	0.42	0.85	1.70	2.54	3.39	4.24	6.36	8.48	....	....	6,630 lb.
6.80	13.10	Standard	600	0.55	1.10	2.20	3.30	4.40	5.49	8.24	....	....	....	3,870 lb.
6.80	13.10	Extra heavy	932	0.33	0.66	1.33	2.00	2.66	3.33	4.99	6.65	8.31	....	6,380 lb.
6.80	13.10	Double extra heavy	1,212	0.26	0.52	1.05	1.57	2.10	2.62	3.92	5.22	6.53	7.85	8,120 lb.
Height 30 ft. Above Ground Line														
5.00	11.75	Standard	519	1.18	2.36	4.72	7.08	9.43	....	....	....	....	....	2,870 lb.
5.00	11.75	Extra heavy	821	0.71	1.43	2.86	4.29	5.72	7.15	....	....	....	....	4,750 lb.
5.00	11.75	Double extra heavy	1,078	0.56	1.12	2.24	3.37	4.49	5.61	8.42	....	....	....	6,050 lb.
6.35	13.10	Standard	617	0.72	1.45	2.90	4.36	5.81	7.26	....	....	....	....	3,530 lb.
6.35	13.10	Extra heavy	969	0.44	0.88	1.76	2.64	3.52	4.40	6.59	8.79	....	....	5,820 lb.
6.35	13.10	Double extra heavy	1,268	0.34	0.69	1.39	2.03	2.77	3.46	5.19	6.92	8.65	....	7,420 lb.
Height 32 ft. Above Ground Line														
5.90	13.10	Standard	634	0.93	1.87	3.74	5.62	7.48	9.35	....	....	....	....	3,230 lb.
5.90	13.10	Extra heavy	1,002	0.57	1.13	2.26	3.40	4.53	5.66	8.50	....	....	....	5,340 lb.
5.90	13.10	Double extra heavy	1,320	0.44	0.89	1.78	2.68	3.57	4.46	6.68	8.92	....	....	6,800 lb.
Height 34 ft. Above Ground Line														
5.45	13.10	Standard	649	1.19	2.38	4.76	7.15	9.53	11.90	....	....	....	....	3,030 lb.
5.45	13.10	Extra heavy	1,034	0.72	1.44	2.89	4.33	5.77	7.22	10.82	....	....	....	5,000 lb.
5.45	13.10	Double extra heavy	1,369	0.57	1.14	2.27	3.40	4.53	5.67	8.50	11.34	....	....	6,360 lb.

the pole and under these conditions, it would appear that it is the economical thing to do. The appearance of a stubbed line is rather objectionable particularly in city territory and this would have to be taken into consideration, where poles are set on city streets. Practically all the companies interviewed are experimenting with patent stubbing clamps and are discontinuing the method of bolting and wrapping. From information available, it appears that the cost is practically the same for each method as the patent method is much quicker installed than the old system. The cost as given by different companies using the patent clamps varies from $10 to $18.50 per pole. A number of different types of concrete stubs have been on the market and at present there is one stub made of reinforced concrete which is cast in two half-sections. These stubs are rather heavy to handle, but when installed make a neat and permanent job.

The cost of the stub is about $15 and the ordinary installation cost would vary from $10 to $15. This particular equipment would be well adapted to poles which carry heavy loads and which would be very expensive to change, but could be reinforced with the concrete stub at a reasonable cost and make a very satisfactory job.

Tree Trimming Method and Procedure

Most of us are familiar with the trouble encountered when trees come in contact with power lines or communicating lines. This creates a hazard both to the public, in case the wires are burned down and are within reach of the ground, and to the utility company's equipment and the consumer's service. Trimming therefore is resorted to to provide adequate clearance and safety. This work can be done in such a manner that the result is not only effective, but frequently a benefit to the appearance of the trees and landscape. In order to insure this trimming being done properly, only experienced men should be allowed to work on tree trimming gangs and should be equipped with the most modern tools and ladders to clear the lines safely and properly.

It is the general practice of the companies operating in the state to make either an annual or semi-annual job of trimming, although in many cases it is necessary to trim more often where permission cannot be secured to trim sufficiently to last for a year. In localities where it is necessary to secure a permit to trim trees, it is advisable to make an inspection of the area and note location of trees which need trimming so that permits may be secured covering the entire area. In the southern part of the state it is the general practice of the county forester to make an inspection of each location where permits have been requested before the permission to trim is given. By having a list prepared covering the whole area this inspection can be made with much less effort and save not only the time of the county forester, but the time of the utility man who generally accompanies the forester on this inspection.

The disposition of the brush and trimmings is an item that can cause a great deal of dissatisfaction and trouble among property owners if not properly handled. Many cases have been noted where the brush and cuttings from the trees were not properly cleaned up or were not cleaned up at all with the result that serious complaint has been made against the company involved, which means that more difficulty will be experienced in securing permission to trim trees in the future. If trees are properly trimmed and the brush disposed of either by burning on vacant lots or hauling it to city dumps and disposing of it, it is not difficult to get permission to trim trees where such requests are reasonable. There are trees which should never be trimmed and where this is done without permission it creates a very unfortunate situation between the property owners and the utility.

It has been found in many instances that a city inspector or county inspector will accompany the tree trimming gang at the expense of the utility and supervise the trimming of the trees in a manner which is satisfactory to the county or city. He also deals with the property owners and relieves the utility of the necessity of securing permission from the owners before trimming is done.

Tree wire has been used to some extent by a number of the utilities and as far as any reports have been received seems to be quite satisfactory although the expense is considerably more than ordinary weatherproof wire. However, this is a possible means of taking care of tree conditions where permission for trimming cannot be secured.

Wooden Poles vs. Steel Poles

The committee has not been able to collect a great deal of data on this subject. The following comparison of cost and physical data has been submitted by one member company with the statement that the cost in most cases is considerably higher than average due to the very rough country over which the line was built and also that a large amount of brushing was required together with incidental expense incurred in maintaining the crew in a mountain resort. The poles used in this line had a top dimension of 15 x 15 in., the dimension at the ground line being 24 x 24 in., and the bottom dimension 8x 8 in. The poles were steel latticed, galvanized and bolted and were 40 ft. in length.

Recently there has been developed a fluted tubular steel pole for distribution and transmission work, which is also adapted to combination ornamental street lighting and distribution circuits. These poles are made in several lengths, varying from 22 to 34 ft. above the ground line. The top diameter varies from 5.45 to 7.7 in. and the bottom diameter from 10.1 to 13.1 in. The following table gives length, weight and deflections at different loads. We have no information from any companies using this type of pole and therefore cannot give any comparisons with wood poles. The figures that have been obtainable would indicate that the price on this type of pole would vary from $4 to $8 per ft., depending on the weight of pole desired.

A steel tube pole has been developed which is very well adapted for substation get-a-way poles where the circuits are brought out from the station underground to a riser pole and from this point are carried overhead. A number of these poles have been installed in Los Angeles varying from 54 to 84 ft. in length. The poles are circular in form and are slightly tapered, and where they are used as riser poles the conduits are carried inside the pole from below the ground line to whatever point on the pole it is desired to carry the circuits overhead. The poles are made in sections approximately 20 ft. in length and are bolted together in such a manner that the pole can be lined perfectly. On one installation in Los Angeles the pole carries six 3-in. conduits and another installation carries two 6-in. conduits inside the pole. The price of this type of pole varies from $7 to $8 per foot, depending on the number of crossarms and number of conduits supplied.

In May, 1927, a number of tests were conducted to determine the strength and deflection of a number of pressure treated Douglas fir poles.

Pole-Line Construction Tools and Equipment*

It is intended in this report to cover for the most part only tools or equipment which have been designed for some particular work by the several companies and which are not carried as standard equipment by the jobbers.

The subject matter of the report includes principally rope specifications, fiber blocks, truck arrangement, portable flood lights, pike-pole points, pole gin, arc-lamp wagon, pole dollies, and compressor for painting ornamental posts.

Rope

It is believed that rope when used in connection with pole-line construction is a very important item and that often its quality is not given adequate consideration at the time of purchase. Therefore the specifications as submitted by the Southern California Edison Company are given herewith. These specifications do not discriminate against any manufacturer, but make acceptable only rope the quality of which is above a certain standard.

Specifications for Manila Rope

1. General.

(A) These specifications shall cover all sizes of manila rope purchased.

(B) Purchases shall be upon a price-per-pound basis, gross weight. Gross weight shall be understood to include the weight of the rope and the burlap dunnage necessary to maintain and protect the coil. The weight of the covering ,etc., at no time is to exceed 2½ per cent of the gross weight.

(C) Marking of deliveries—Every coil or package, when delivered, shall bear a tag which shall contain, in addition to such other information required by the purchasing agency, the circumference diameter and the approximate length of the rope.

2. Materials.

(A) Marking of bales—No fiber shall be used unless contained in bales from central portion of which protrude the original stamped

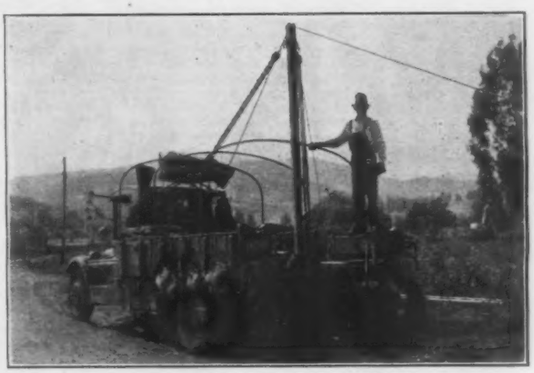


Fig. 1. A line truck used by the San Diego Consolidated Gas & Electric Company.

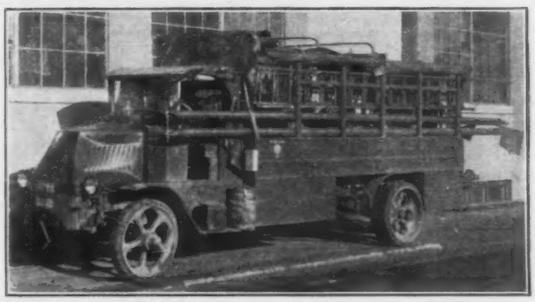


Fig. 2. A standard line truck of the Pacific Gas and Electric Company.

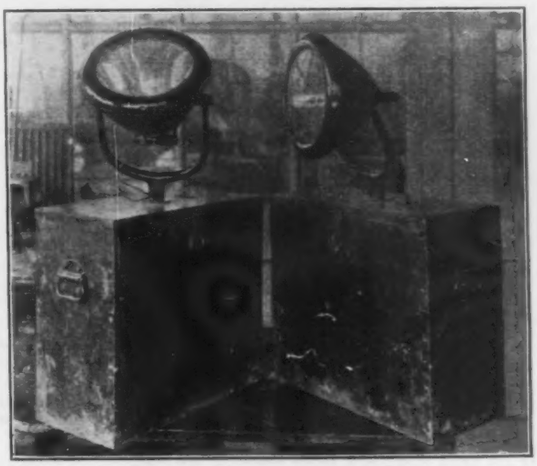


Fig. 3. Portable floodlights used by the Pacific Gas and Electric Company.

* Report of subcommittee of overhead systems committee—F. E. Dellinger, chairman. K. B. Ayres, E. R. Banks, W. P. Champion, J. E. Crilly, P. Diederich, P. J. Freygang, C. E. Heath, G. H. Hagar, S. W. Kephart, G. A. MacDonald, E. A. McGinty, Howard Pratt, S. P. Russell, A. E. Strong, C. W. Walker.

tags as placed therein by the Government Philippine Islands inspector.

(B) The contractor shall furnish any information or data requested by the buyer, from any specified source respecting the grades and quantities of manila fiber which has been purchased for use in the rope to be manufactured and the disposition of such purchases.

(C) Standard Rope—No fiber other than "Manila" (Abaca) fiber shall be used; and no grade of "Manila" lower than Government Grade I shall be used in any size of rope. (It is to be noted that Grades "G" and "H" are lower than "I.")

Government Grades S1 and S2 may be used, and shall be considered equivalent to Government Grades F and I, respectively.

A mixture of grades is allowable, with the following limitations:

(1) For rope up to and including 1⅛ in. in circumference not more than 25 per cent of Government Grade F shall be used, the balance to be of higher grades.

(2) For rope 1¼ up to and including 1¾ in. in circumference not more than 40 per cent of the Government Grade F shall be used, the balance to be of higher grades.

(3) For rope 2 in. in circumference and larger not more than 50 per cent of Government Grade I shall be used, the balance to be of higher grades.

(D) No manufacturer shall submit under these specifications any rope which is inferior in quality of fiber to that which he uses in his own first-grade rope.

3. Construction.

(A) **Lay**—The rope shall be 3-strand, medium-laid unless other lay is specified by purchaser.

(B) **Four-strand rope**—Four-strand, medium-laid rope when ordered shall not be more than 7 per cent heavier than 3-strand rope of the same size and shall have at least 95 per cent of the strength required of 3-strand rope of the same size. Other requirements are the same as for 3-strand rope.

(C) **Lubricant content**—Rope shall contain oil of a good cordage grade (for internal lubrication) of not less than 8 per cent nor more than 12 per cent of the weight of the finished rope. No substance for the purpose of loading or weighing the rope shall be added.

(D) Rope shall be manufactured with a streamer, tape, colored yarn or other distinctive marker worked into the rope as a means of identification to indicate the manufacturer.

(E) Sizes shall be as shown under Item 4 with "plus or minus" tolerances as follows:

TABLE I—Rope Tolerances.

Circumference of Rope—Inches	Tolerance—Inches
¾ to 1¾	1/8
2 to 2¾	5/16
3 to 3¾	¼
4 to 5	5/16
5½ to 7	⅜
7½ to 9	½
9½ to 10½	⅝
11 to 12	¾

4 Weight and Strength.

Maximum weights and minimum breaking strengths shall be as follows:

having an inside diameter of not less than 7 in. The length between inside ends of splices shall be not less than 5 ft. for all sizes of rope. Splices should be made carefully to insure specimen breaking in body of rope, and should be soaked in water for at least four hours prior to test.

(2) If the specimen fails to meet the strength requirements this test shall be repeated if the break occurs at the splice or holding device.

(3) Other methods of holding in lieu of the eye-splice may be used provided there is a length of at least 5 ft. between holding devices.

(4) The speed of the straining head of the testing machine shall not be over 4 in. per min. when under no-load.

(C) Tests and rejections—All tests and rejections shall be made in compliance with U. S. Government Specifications No. 61 for Manila rope and shall be at the expense of the purchaser.

(D) Nothing herein contained shall be considered as conflicting with those portions of U. S. Government Specifications No. 61 herein referred to.

Fiber Blocks

Very little information respecting "blocks" has been received by the committee, but there was evidenced some interest in "fiber blocks" at both the Los Angeles and the San Francisco meetings and the experience of the Los Angeles Gas and Electric Corporation is submitted.

Comparison of costs between wood, steel and fiber blocks, only one manufacturer quoting on fiber:

TABLE III—Block Costs.

Size	Sheave	Wood Block	Steel Block	Fiber Block
4 in.	2	$1.96	$1.24	$ 3.70
5 in.	2	2.08	1.29	.....
6 in.	2	2.44	1.57	7.90
6 in.	3	3.40	2.42	11.05
8 in.	3	4.96	3.30	22.75

Believing that the quotation on the fiber blocks was unreasonably high a number of wood blocks which had been discarded were taken apart and the metal parts which were in good condition were salvaged, fiber was purchased and milled to fit the salvaged parts which were assembled into the fiber at the following cost:

TABLE IV—Block Costs.

Size	Sheave	Fiber and Milling	Salvaged Parts	Assembling	Total
4 in.	2	$2.75	$0.65	$0.70	$4.10
6 in.	2	4.10	0.69	0.70	5.49
6 in.	3	5.30	1.76	0.90	7.96
8 in.	3	6.30	2.10	0.90	9.30

TABLE II—Maximum Weights and Minimum Breaking Strengths.

Approximate Diameter Inches	Circumference Inches	Approximate Feet per Coil	Approximate Gross Weight per Coil—Lb.	Maximum Net Weight per Foot of Rope—Lb.	Minimum Feet per Lb.	Minimum Breaking Strength—Lb.	200 D2 Lb.
3/16 (6 yarn)	½	3,000	45	0.015	66.600	590	7.0
¼ (6 yarn)	¾	2.750	55	0.020	50.000	700	12.5
5/16 (9 yarn)	1	2,250	65	0.029	34.500	1,200	19.5
⅜ (12 yarn)	1⅛	1,620	66	0.041	24.400	1,540	28.2
7/16 (15 yarn)	1¼	1,200	70	0.054	18.500	1,750	38.2
15/32 (18 yarn)	1⅜	1,200	80	0.064	15.600	2,100	44.0
½ (21 yarn)	1½	1,200	90	0.074	13.500	2,450	50.0
9/16	1¾	1,200	126	0.103	9.710	3,150	63.4
⅝	2	1,200	160	0.131	7.530	4,000	78.2
¾	2¼	1,200	198	0.162	6.170	4,900	112.5
15/16	2½	1,200	234	0.191	5.230	5,900	132.0
⅞	2¾	1,200	270	0.221	4.550	7,000	153.0
1	3	1,200	324	0.265	3.770	8,200	200.0
1 1/16	3¼	1,200	378	0.309	3.240	9,500	226.0
1 1/8	3½	1,200	432	0.353	2.830	11,000	252.0
1 ¼	3¾	1,200	504	0.412	2.430	12,500	312.0
1 5/16	4	1,200	576	0.470	2.130	14,200	345.0
1 ⅜	4¼	1,200	648	0.529	1.890	16,000	378.0
1 7/16	4½	1,200	720	0.588	1.700	17,500	450.0
1 15/32	4¾	1,200	810	0.662	1.510	19,500	490.0
1 ½	5	1,200	900	0.735	1.360	21,500	528.0
1 9/16	5½	1,200	1,080	0.882	1.130	25,500	612.0
2	6	1,200	1,296	1.06	0.943	30,000	800.0
2 1/16	6½	1,200	1,500	1.23	0.813	34,000	850.0
2 ⅛	7	1,200	1,764	1.44	0.694	38,500	1,012.0
2 3/16	7½	1,200	2,016	1.65	0.606	43,500	1,250.0
2 ¼	8	1,200	2,304	1.88	0.532	49,000	1,380.0
2 5/16	8½	1,200	2,580	2.11	0.474	55,000	1,660.0
3	9	1,200	2,916	2.38	0.420	61,000	1,800.0
3 1/16	9½	1,200	3,240	2.65	0.377	67,000	1,950.0
3 ⅛	10	1,200	3,600	2.94	0.340	73,000	2,120.0
3 5/16	10½	1,200	4,000	3.25	0.308	79,600	2,190.0
3 3/16	11	1,200	4,400	3.57	0.280	86,400	2,450.0
3 ⅜	11½	1,200	4,800	3.90	0.256	93,600	2,530.0
3 ¾	12	1,200	5,200	4.24	0.236	101,000	2,812.0

5 Lengths.

Lengths purchased shall be in coils or half-coils as specified in Item 4.

6.—Inspection, Tests and Rejections—(A) Inspection shall be at the point of delivery unless otherwise specified.

(B) Test specimens of strength tests:

(1) The specimen for determining the breaking strength when eye-splice is used shall have an eye-splice in each end

Truck Arrangement

Figure 1 shows a truck such as is used by the San Diego Consolidated Gas & Electric Company for line construction. The truck is equipped with tool and material boxes the covers of which are used as seats for the men while traveling. Mounted on the rear of the

The cost of one-third that of new wood blocks was used as the cost of the salvaged parts. Taking into consideration the longer useful life of the fiber blocks as compared with wood or steel, it is economical at the above cost to make over old wood blocks into fiber as they become broken. In addition to the economic advantage they are much preferred by the linemen who use them.

truck is a boom which is used for raising poles. The truck also is equipped with a winch and nigger-head which are located behind the cab so that the winch line may be passed over a pulley on the top of the boom and used as the raising power in elevating poles. To keep the pole from swinging sideways a line on each side is required.

Figure 2 shows a standard line truck of the Pacific Gas and Electric Company equipped with drawers and

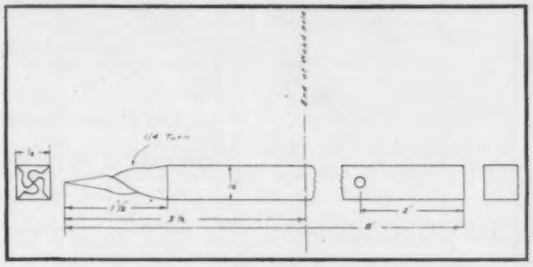


Fig. 4. A twisted-point pike pole designed by F. A. Brown of the Southern California Edison Company.

compartments for tools and material. Standard winches are mounted in front of the body with 150 ft. of ½-in. flexible steel cable for use with a pole derrick of sufficient height to raise poles of any length up to 70 ft.

A movable capstan-head slides into a hollow shaft on the right hand side of the truck for use in raising or lowering transformers, pulling wire, etc. A vertical roller mounted on the rear corner of the truck allows the fall-line to pass from the capstan-head to a snatch-block on the pole so that transformers may be unloaded or loaded on the truck while in a position at the foot of the pole.

In connection with the arrangement of truck bodies, it is recommended strongly that a separate box or com-

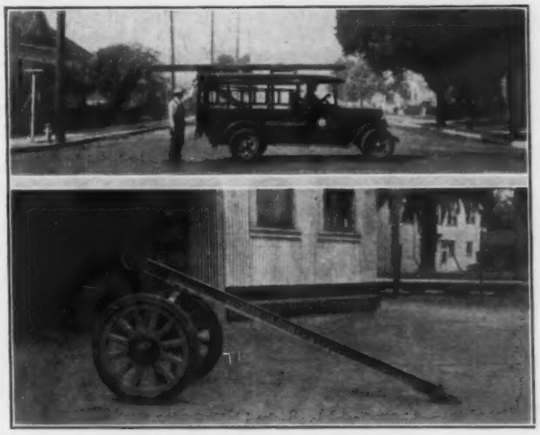


Fig. 5. Arc lamp truck of the Los Angeles Bureau of Power and Light with ladder folded for traveling (above). Pole dolly used by Los Angeles Bureau of Power and Light (below).

partment be provided for rubber goods and that this box be made waterproof for protection against rain. When men are required to ride on trucks, no tools or small material should be allowed on the bed of the truck in such a manner that it could cause the men to trip or stumble while getting on or off the truck.

Portable Flood Light

Figure 3 shows portable flood light for the use of crews called on to do emergency work at night. The equipment consists of a 180-amp.-hour storage battery mounted in a box provided with handles. The leads from the battery are connected through a switch to a 32-candle-power lamp which is placed in an automobile headlight and mounted on a trunion base on the top of the box.

Pike Poles

Figure 4 represents a pike-pole point which was recently developed by Fred A. Brown of the Southern California Edison Company and which has been given a trial by several companies and has proved to be a great improvement over all other points now in general use. This point when stuck into a pole will not slip out, nor can it be pulled out without giving it a slight turn.

The San Diego Consolidated Gas & Electric Company uses a 1-legged "dead man" in place of the usual

Fig. 6. (Left) Arc lamp truck of Fig. 5 shown with ladder extended in working position. (Right) Truck with compressor and tower used by Los Angeles Bureau of Power and Light in painting ornamental posts.

"scissor" type and finds that this type of "dead man" is very much more convenient due to its lighter weight and shape. It is made of wood equipped with steel fittings at the top for gripping the pole and a steel point at the bottom to prevent slipping. The length from the bottom to the place where the pole is held is about 8½ ft. and is 3⅛ in. square.

Arc-Lamp Truck

An arc-lamp truck of the Los Angeles Bureau of Power and Light is shown in Figs. 5 and 6. The back of the truck is reinforced to support an extension ladder which is hinged to the top of the truck in such a manner that it may be lowered and folded along the top of the truck as shown in Fig. 5 while traveling and quickly raised to the position as shown in Fig. 6 for arc-lamp work.

Pole Dolly

A pole dolly used by the Bureau of Power & Light is shown in Fig. 5. A chain is placed around the pole and the tongue of the dolly raised until the hook at the rear may be hooked into the chain and when the tongue is lowered it raises the pole free from the ground in a position for towing.

Compressor for Painting Ornamental Posts

Figure 8 shows a truck equipped for use in spraying ornamental lighting standards. In the forward compartment is an air compressor and in the rear is a place for storing paint, while in the center is a platform which may be elevated or lowered to suit the operator, the motor which operates the platform being controlled from the top of the platform. When the platform is lowered the several sections telescope making a very compact arrangement. This truck is being used by the Bureau of Power & Light.

Miscellaneous

Several of the companies failed to send in any information as to the special tools which they are using, therefore it is probable that many interesting develop-

ments have not been included in this report. Also there were several items submitted which required that tracings be made to describe them properly and which are not included because of lack of time to get the necessary work finished. Among these items are "wire gins", pole gripping device, portable pole platforms, warning signs, bolster for hauling poles on the body of trucks, towing hooks and fixtures, hook for holding hand line pulley on pole or cross-arm, and several items submitted by manufacturers and jobbers which information is available to all of the companies through the representatives of the manufacturers.

Prime Movers Committee Reports[2]

Condensing Equipment*

This report contains the following data:

1. Report from C. W. Wiggins, San Diego Consolidated Gas & Electric Company on electrolytic protection of a condenser.
2. Reports from R. F. Leefeld, Los Angeles Gas & Electric Corporation on (a) Effect of increasing amount of air and carbon-dioxide gas in condenser cooling water, (b) Effect of fresh circulating water under partial vacuum on condenser tubes, (c) Tin and lead lined tubes.
3. Report from H. T. Shirley, San Joaquin Light & Power Corporation on cleaning of a condenser which uses fresh water for cooling.
4. Report from E. H. Roseberry of the Ingersoll-Rand Company and O. H. Hedrick, Jr., of the City of Pasadena, on air leakage of a condenser.
5. Report from Scott Jensen, Southern California Edison Company on condenser tubes and effect of electrolytic protection. Also a series of photographs of tubes from several condensers in California.

Report from San Diego Consolidated Gas & Electric Company

Condenser tube failures have been reduced considerably since last year's report, and this is thought to be due to electrolytic protection. The company furnishes 500-volt d.c. power to the local street railway company. A large amount of street railway current was returned

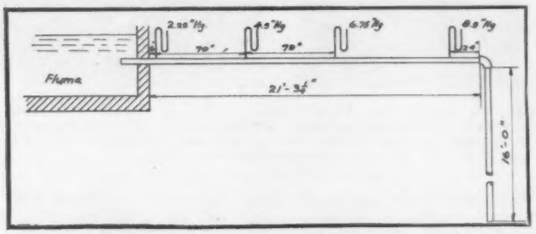


Fig. 1. Arrangement used in testing condenser tubes under partial vacuum, Los Angeles Gas and Electric Corporation.

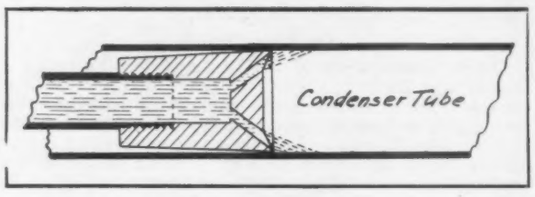


Fig. 2. Condenser tube cleaner and piping layout for cleaning condenser with soda ash, Midway steam plant, San Joaquin Light & Power Corporation.

to the station through pipe lines, cables, etc., and this current was believed to be the primary cause of tube failures.

With the co-operation of the street railway company and the telephone company, the railway returns were insulated between rail connection and the negative bus in the plant and the negative bus also was insulated. Proper resistances were placed in the returns to give equal potential gradient. At the power plant, telephone

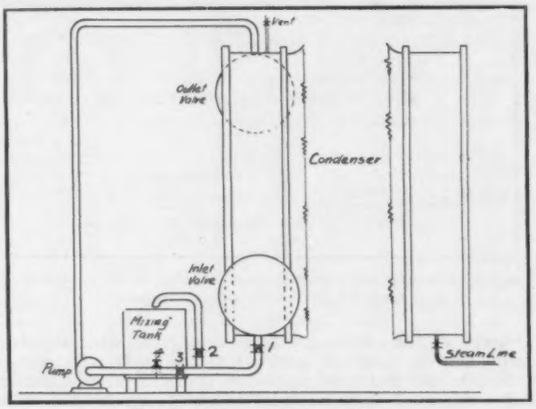


Fig. 3. Same equipment as Fig. 2.

cable sheaths, gas mains, power cable sheaths, and steam mains were each connected to the negative bus through individual resistances.

Resistances were adjusted to make all points on the rails at higher potential than the cable sheaths, gas mains, etc. The upper and lower halves of the condenser tube sheets at both ends were bonded together and connected through resistance (one for each condenser) to the negative bus. Resistances were varied so that the tube sheets became slightly negative with respect to the condenser shell. This required a current of about 20 amp. from the tube sheets to the negative bus.

A 28,000-sq.-ft. condenser used with a 15,000-kw. turbine was placed in service February 14, 1923. Thirty-eight days later three pitted tubes were removed. After a year and two weeks operation 448 tubes had failed and a new set of 5,348 tubes was installed. The second set of tubes has been in service since April 14, 1924.

To December 15, 1927, 1,359 tubes had failed and 1,057 new ones had been installed. Since March 1, 1927, when 586 tubes that had failed were replaced, 59 tubes have been lost, or only six per month. This is considered a great improvement over former conditions.

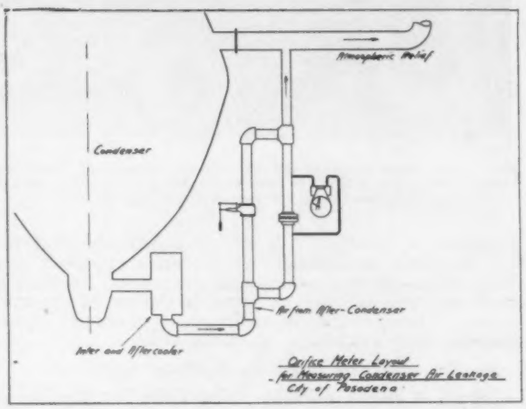


Fig. 4. Orifice meter layout for measuring condenser air leakage at No. 6 condenser, City of Pasadena.

[2] **F. G. Philo,** Southern California Edison Company, chairman. **F. R. Knight,** Los Angeles Gas and Electric Corporation, vice-chairman. **General Electric Company:** H. E. Fuqua, R. F. Monges, E. E. Valk. **Great Western Power Company:** H. S. Markey. **Ingersoll-Rand Company:** V. M. Peck, E. H. Roseberry. **Los Angeles Gas and Electric Corporation:** R. F. Leefeld, E. G. MacDonald, Weller Reed, J. G. Rollow, C. H. Zeise. **Pacific Gas and Electric Company:** L. D. Burlingame, C. H. Delany, F. T. Ellis, V. F. Estcourt, H. N. Mosher, M. E. Mulkey, R. C. Powell, C. E. Steinbeck, J H. Stott. **San Diego Consolidated Gas & Electric Company:** E. D. Sherwin, C. W. Wiggins. **San Joaquin Light & Power Corporation:** A. Y. Meudell. **Southern California Edison Company:** H. C. Bennett, G. K. Gordon, C. L. Hathaway, Scott Jensen, L. J. Kraps, W. H. Short, W. E. Thompson, H. Waldorf, R. A. Wallingford, Raymond Wilcox. **The Southern Sierras Power Company:** V. E. Johnson. **Westinghouse Electric & Manufacturing Company:** R. A. Hopkins.

* Report of subcommittee of the prime movers committee—Scott Jensen, chairman.

A second 15,000-kw. turbine with a condenser of 20,000-sq.-ft. was placed in service January 22, 1927. The first tube failed in this condenser May 10, and to December 15, 17 had failed in the first pass and 8 in the second pass, or about two tubes per month.

A summary of the tube failures on the 28,000-sq.-ft. condenser gives a clear idea of the improvements effected after a control of the stray currents was established as shown in Table I.

TABLE I—Control of Stray Current.

Period	Time (Months)	Number Tube Failures	Tube Failures Per Month
February 14, 1923, to March, 1924	12.5	488	39
March, 1924, completely retubed the condenser.			
April 14, 1924, to March 1, 1927	34.5	1,300	37.7
March, 1927, installation of electrolytic protection completed.			
March 1, 1927, to December 15, 1927	9.5	59	6.3

Report from Los Angeles Gas & Electric Corporation

Condenser tube test to detect effect of increasing the amount of dissolved air and CO_2 gas in condenser cooling water.

Purpose—To determine whether tube destruction is dependent upon or in proportion to the amount of dissolved air or CO_2 gas in cooling water.

Nature of Test—Three new tubes were installed in condenser (in upper half of north half, in twelfth row down from top in first bank north of middle partition, in eighth, tenth and twelfth vertical columns counting northward from partition). Into the southernmost tube 0.1 cu.ft. per min. of air was injected. The middle tube was used as a check tube. Into the third tube 0.0056 cu. ft. per min. of CO_2 gas was injected.

Arrangement—The air was drawn from atmosphere through a needle valve and a glass sight-feed which rendered continuity of flow observable. Flow was checked occasionally with a voltmetric meter. The CO_2 gas was drawn from two high-pressure steel soda-fountain bottles and glass sight-feed. Rate of flow was checked occasionally with a volumetric meter, and chosen to assure that test would continue at least 60 days.

Both air and gas were conducted by 1/16-in. brass tubes to points approximately 18 in. within intake ends of the respective tubes.

TABLE II—Boiler Test Data.

Duration of test, 80 days, or	115,200 min.
Sea water flowing through East tube (estimated average)	1.3 cu. ft. per min.
Air content of sea water (estimated average)	0.037 cu. ft. per min.
CO_2 content of air content (0.04%, Kent)	0.000015 cu. ft. per min.
Air admitted at rate of	0.1 cu. ft. per min.
CO_2 gas admitted (total 70 lbs. or 57 cu. ft.)	0.005 cu. ft. per min.
Total air entering air test tube	0.137 cu. ft. per min.
Total CO_2 gas entering gas test tube	0.005015 cu. ft. per min.
*Air increase ratio (air tube to check tube)	57 to 1
*Gas increase ratio (gas tube to check tube)	333 to 1

*Note—It may be noted that the air-saturated sea water when subjected to the raised temperature and lowered pressure at the point of test becomes super-saturated, but still can dissolve most of the CO_2 gas applied.

Results—At the conclusion of test the three tubes were removed from condenser and an 8-in. piece cut from each end and from the middle of each tube. These pieces were split lengthwise and half of each mounted together on a wood panel for easy inspection. Inspection of these three sets of samples seems to disclose the following:

Check Tube—Condition clean, corrosion slight, rate of destruction normal.

Air Tube—Condition clean, corrosion but slightly greater than that of check tube.

Gas Tube—Condition discolored by attached carbonate of copper (bluish-green) corrosion several times that of check tube.

Test on Condenser Tubes Using Fresh Water for Cooling

For a number of years pure copper condenser tubes have been used at the Alameda Street station. These tubes have never given any trouble. A few copper test tubes at Seal Beach station failed in a short time due to pitting.

There are two principle differences in operating conditions, sea water is used at Seal Beach station and treated Los Angeles city water at Alameda Street station. This city water contains a great variety of ingredients. It averages considerably warmer than Seal Beach circulating water. The other difference lies in the operating head or pressure.

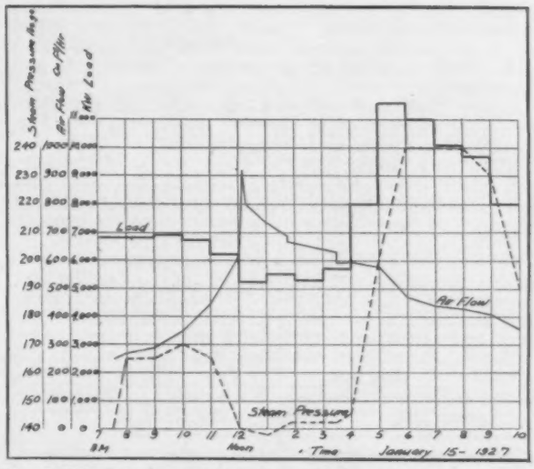


Fig. 5. Air flow from condenser in relation to load and steam pressure, No. 6 condenser, City of Pasadena.

At Seal Beach the circulating pump discharge pressure ranges from 5 to 7 lb. gage and the outlet end on the condenser tubes has a vacuum of from 20 to 24 in. of mercury, depending upon the tide level. The range of course will exceed these figures at times.

The purpose of these tests was to find out if the Alameda Street station condenser circulating water under partial vacuum would act in a manner similar to sea water under a partial vacuum. In other words, is it the vacuum, the ingredients of the water, or a combination of both which makes the difference?

One end of each of the samples is inserted into a hole in the side of the condenser circulating water discharge flume. These tubes lie in a horizontal position. The other end of each tube is connected by means of a hose to a vertical drop-leg of approximately 16 ft. This drop-leg is made of 1-in. condenser tubing.

Pressures were obtained in the horizontal test tubes as indicated in Fig. 1.

These tubes have been under test for approximately 16 months and to date they all are in good condition. Both copper and Admiralty metal are under test.

Tin and Lead-Lined Tubes

In last year's statement some results with lined tubes were reported. It was stated that the tin-lined tubes appeared to be not quite as good as the lead-lined tubes, and that possibly the tin-lined tubes suffered greater deterioration from expanding into the tube sheet. It has been found now that one of the tin-lined tubes failed due to pitting where it was rolled into the tube sheet. The rollers evidently injured the coating. Possible trouble from this cause was anticipated and this was one of the conditions the lining was expected to stand in order to be successful.

Condenser Cleaning at Midway Steam Plant of the San Joaquin Light & Power Corporation

Inspection of the condensers at the Midway steam plant was made in the fall of 1926 after a season's run. The tubes in No. 1 and No. 2 condensers were found to contain a thick coating of dark slimy sludge running the full length of the tubes. Tests made of this slimy matter showed it to be a great insulator, with each tube containing at least a full-sized cup of it.

These condensers are supplied with circulating water from spray and cooling tower ponds situated adjacent to the plant. During the summer months a growth was evident in these ponds, such as algae and other species of small marine vegetation, however. This growth during the past summer has been practically eliminated by the introduction of copper sulphate into the ponds.

It is thought that the slime that was present in the condenser tubes was of a purely vegetable origin, due to the growth mentioned, no scale being present. The condensers previously were cleaned by the use of a tool constructed as shown in Fig. 2. The slimy deposit was

loosened readily by the sharp edges of this tool and flushed out with water. These condensers have 30,000 sq. ft. of cooling surface, with 5,000 and 6,000 tubes each. This made the above method a rather long and dirty job.

As this plant was not operating in the winter of 1927, the following method of cleaning was introduced, Fig. 3 shows the piping arrangement.

Water was turned into the condenser after the inlet and outlet valves were closed until it was over half full. Steam was turned into the condenser through a 1-in. line, as shown, under a pressure ranging from 20 to 30 lb.

Valve No. 3 was closed, valves Nos. 1, 2 and 4 were opened, the pump was started and flow regulated through valve No. 2 so that the water in the mixing tank was held about one-half full. Soda ash (58 per cent light) then was continually mixed in this water until 900 lb. of the soda ash had been mixed and pumped into the condenser. Valve No. 3 then was opened and valves No. 2 and No. 4 closed. Water again was turned into the condenser until it covered the top row of tubes.

Steam was flowing continually into the condenser, heating the water, where it was held between 175 and 200 deg. F. during the period of three days while the solution was circulated. The steam was shut off and the condenser allowed to cool so that no undue stresses would be put upon it. Then cool circulating water was turned into it. When the condenser was sufficiently cool the circulating pump was started and the condenser was flushed out.

Upon inspection, the tube sheet was clean. A swab and rod were pushed through several tubes in various parts of the condenser and they also were found to be clean. Although an average of five days per condenser was used in this method of cleaning due to the necessary connections, piping ,etc., having to be made up, it is believed after close observation of the solution and tests made during the circulation through the condensers, that the action on the deposit in the condensers was very rapid and with the necessary equipment made up and the use of hot water from sources other than heating it in the condenser, the total time necessary for the cleaning of a condenser under this method can be accomplished in a period of from six to eight hours.

The proportions of soda-ash to water used in this method of cleaning corresponds approximately to a barrel per 1,350 gal.

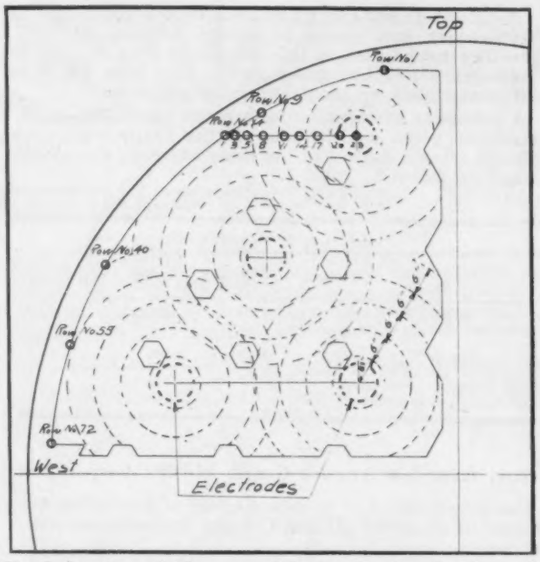


Fig. 7. Locations of tubes removed for investigation of pitting and corrosion, No. 9 condenser, Long Beach steam plant.

Report on Air Leakage at the No. 6 Condenser of the City of Pasadena

Reaction turbine, 10,000 kw., condenser 14,250 sq. ft.

In order to measure the air leakage on No. 6 condenser, a by-pass with a quick opening valve was installed in the fourth discharge line from the evacuating jets. See Fig. 4. A pair of standard flanges was inserted in the line to receive an orifice disc. After starting out with a 3/16-in. orifice and gradually increasing the size, it was found that a 5/8-in. orifice would not cause a back-pressure of more than from 4 to 5 in. of water under normal conditions. Incidentally the static pressure was substantially the same as the differential pressure due to the fact that the line discharged to atmosphere.

During the preliminary setting-up of this meter, water U-tubes were used to read the pressure, but these

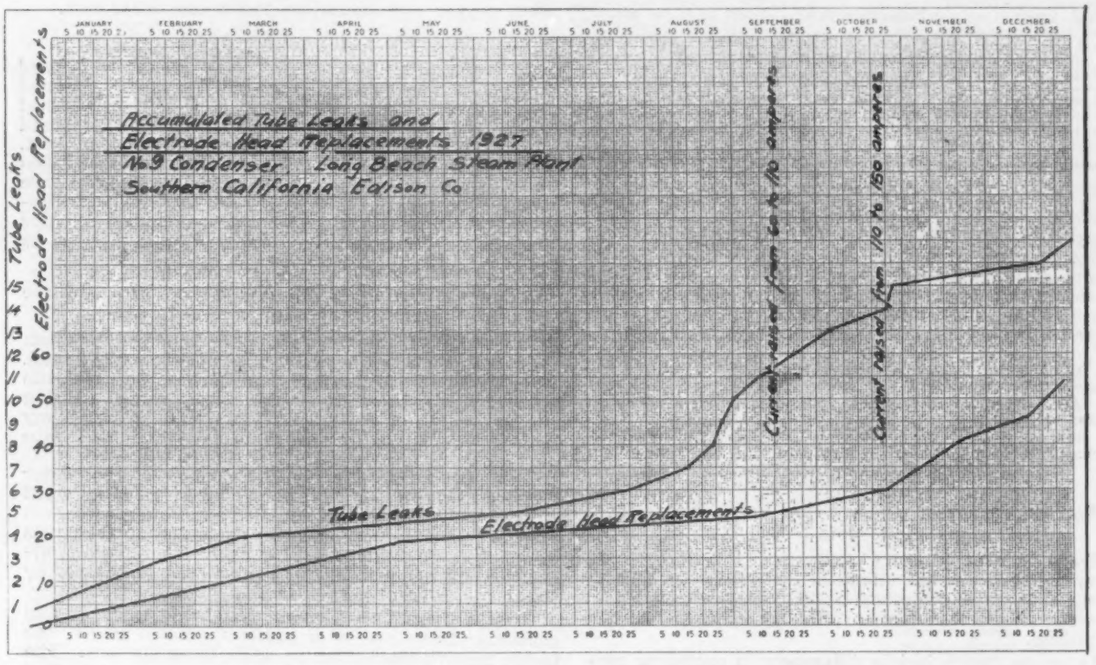


Fig. 6. Accumulated tube leaks and electrode head replacements in 1927, No. 9 condenser, Long Beach steam plant, Southern California Edison Company.

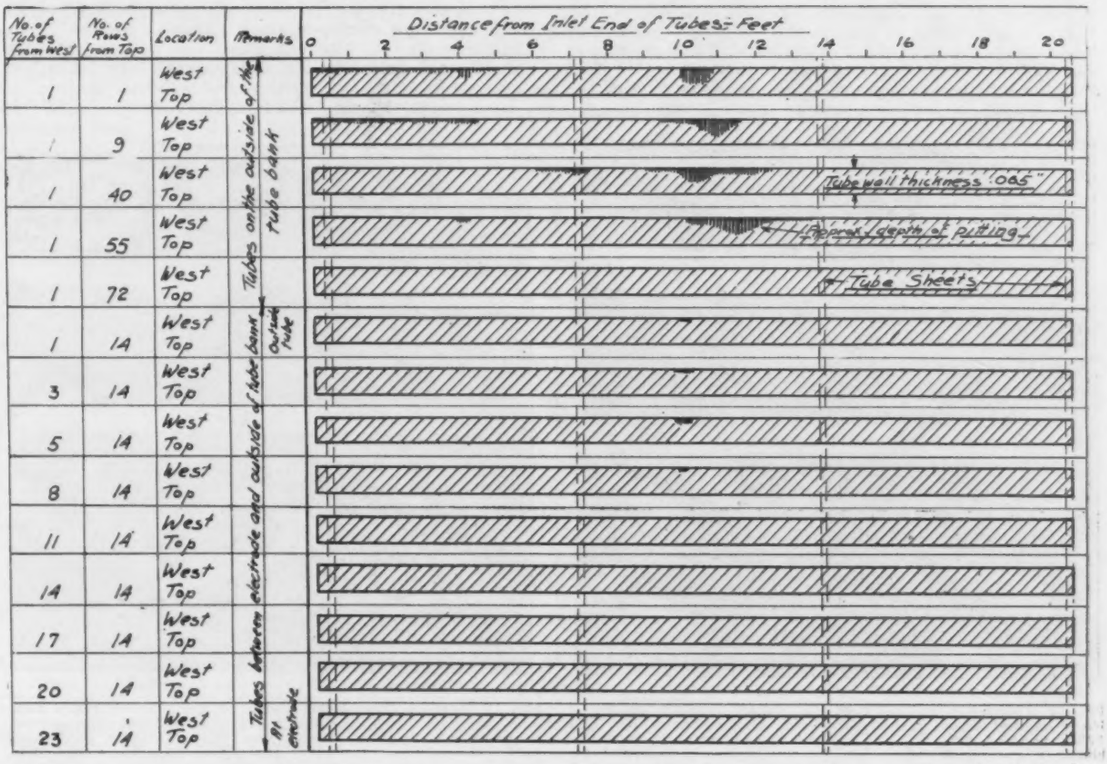

No. of Tubes from West
No. of Rows from Top
Location
Remarks
Distance from Inlet End of Tubes - Feet
0 2 4 6 8 10 12 14 16 18 20
1 1 West Top
1 9 West Top
1 40 West Top
1 55 West Top
1 72 West Top
1 14 West Top
3 14 West Top
5 14 West Top
8 14 West Top
11 14 West Top
14 14 West Top
17 14 West Top
20 14 West Top
23 14 West Top
Tubes on the outside of the tube bank
Tubes between electrode and outside of tube bank
All electrode
Tube wall thickness .065"
Deepest depth of pitting
Tube Sheets

Fig. 8. Pitting of tubes taken from No. 9 condenser, Long Beach steam plant, as indicated in Fig 7.

were of course unsatisfactory for a continuous record. Then a 10-in. differential pressure meter was installed and the flow recorded. A study of the leakage together with the steam pressure and turbine load, Fig. 5, indicates that the air flow increases when the steam pressure drops below 150 lb. gage and the load drops down to 5,500 kw. At this point the pressure in the cylinder equalizing pipes changes from positive pressure to vacuum, and air is drawn in through the high-pressure sealing gland.

Any condition that will create a vacuum in the high-pressure sealing gland will cause a considerable increase in the air leak. Usually there is no appreciable vacuum drop until the air flow has reached 500 to 600 cu. ft per hour. When this occurs, the vacuum can be brought back readily by adding another primary steam jet.

It may be noted that the increase in air flow occurs very suddenly, when the conditions are favorable for air leakage, but that the subsequent decrease is gradual. This would indicate that it takes a comparatively long time to remove the air from the air vapor mixture.

Before accurate data on the air flow were obtained it was thought that the greatest air flow would be obtained at the time of the greatest steam consumption of the turbine. However, it appears that the air entering the turbine with the steam is quite inconsequential when compared with a small air leak.

Eastern Data on Air Leakage at Condensers

Daily readings of a 25,000-kw. condenser at Broad River Power Company show from 5 to 9 cu. ft. per min. leakage, and on a 60,000-kw. unit at Buffalo General Electric the leakage is from 5 to 8 cu. ft. per min. The New York Edison 35,000-kw. unit operates with from 9 to 10 cu. ft. per min. leakage, but when the valve is opened adding 12 cu. ft. per min., the vacuum drops not more than 0.01 in. These condensers have external air coolers.

Report from Southern California Edison Company On Tube Failures in No. 9 Condenser

Since this condenser was started, July 10, 1926, a total of 15 tubes have failed to date. Most failures have occurred on the outside rim of the tube bundle in the upper west quarter. Four electrodes are located in each end of each quarter for electrolytic protection, in all, 32 electrodes. The average current used on these electrodes totaled 60 amp. until September 15, 1927, 1.9 amp. per electrode or 0.8 amp. per 1,000 sq.ft. (cooling surface 75,000 sq. ft.) or 0.004 amp. per tube

Fig. 9. (Above) A 1-in. pure copper test tube from No. 1 condenser, Seal Beach plant, Los Angeles Gas and Electric Corporation, installed July 31, 1925, removed April 7, 1926. Dark spots are original copper surface, balance copper chloride and copper sulphate. (Below) Same as above except green coating removed with wire brush, leaving only pure copper.

(14,300 tubes). The current was raised to 110 amp. on September 15, 1927, and to 150 amp. on October 24, 1927, corresponding to 2 amp. per 1,000 sq. ft. No tube leaks have occurred since October. Whether this is due to the increased amount of current or to the fact that the turbine has been idle a considerable part of the time during the last few months is not known.

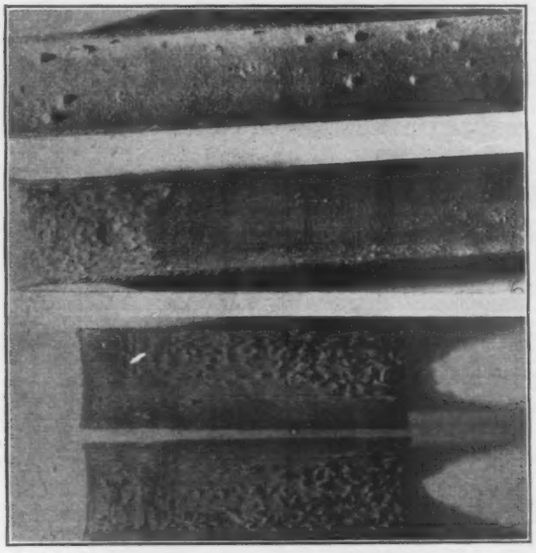


Fig. 10. (Above) A tin-lined tube 1-in. outside diameter, condenser No. 1 at Seal Beach, installed Sept. 11, 1926, plugged Sept. 22, 1927, removed Oct. 2, 1927. Note the blisters. Under each blister is a pit. (Below) A 1-in. brass tube No. 16 B.W.G. from condenser No. 1 at Seal Beach, installed June 2, 1925, removed October, 1927. Swaged section due to use of metallic packing.

From starting operation to November 1, 1927, the turbine was operated 64.8 per cent of possible hours. From November 1, 1927, to January 10, 1928, the operation has only been 42 per cent of possible hours. The electric current to the electrolytic protective system always is on, whether the turbine is operating or idle. The electrode replacements increase approximately proportional to the current, which would be expected. With 60 amp. the average replacement was 1.8 heads per month, with 110 amp. the replacement was 3.8 heads per month, and is now in the neighborhood of 10. Each cast iron electrode head (Anode) weighs 37 lb. when new and is replaced when the weight has been reduced to 6 or 8 lb. The accumulated tube leaks and electrode head replacements are shown in Fig. 6

Because most tube leaks happen to be on the outside of the tube bundle where the protection from electrodes would be least effective, it was reasonable to believe that some relation existed between the electrode location and the development of tube pitting. In order to establish this relation, if any, a series of tubes was

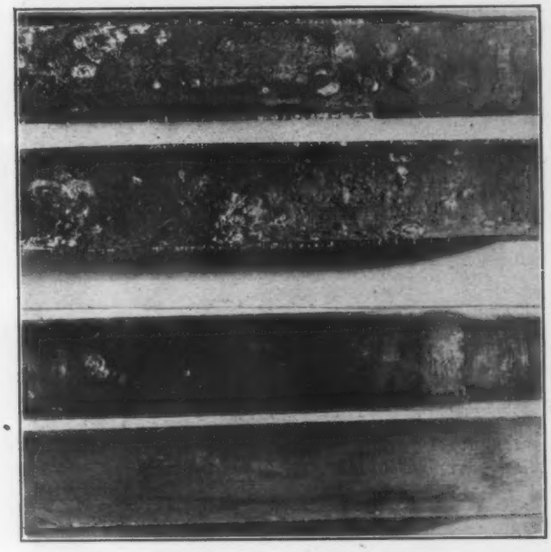


Fig. 11. (Above) A 1-in. No. 16 B.W.G. brass tube from the second pass of condenser No. 1 at Midway steam plant. Tube placed in service in 1921, removed for inspection 1927. Inlet end of tube is shown, very little pitting. Fresh water from cooling towers and ponds used for cooling. Some copper sulphate added to water to prevent vegetable growth. (Below) A tube from No. 1 condenser at Midway steam plant first pass, showing both inside and outside at inlet end; very little scale and a thin deposit of mud. Packing used was asbestos expansion rings and metallic packing.

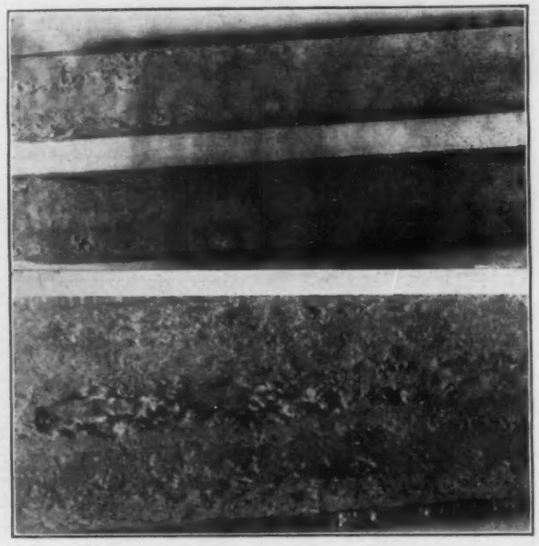


Fig. 12. (Above) Downstream end of a nozzle which fits a 1-in. condenser tube on the inlet side, taken from first pass, east section, condenser No. 8 Long Beach steam plant, installed September, 1926, removed Nov. 1, 1927. (Below) A 1-in. brass tube from No. 9 condenser Long Beach steam plant, second pass, west section. Tube installed July 10, 1926, plugged Feb. 9, 1927, removed March 13, 1927. Tube leak may be noted.

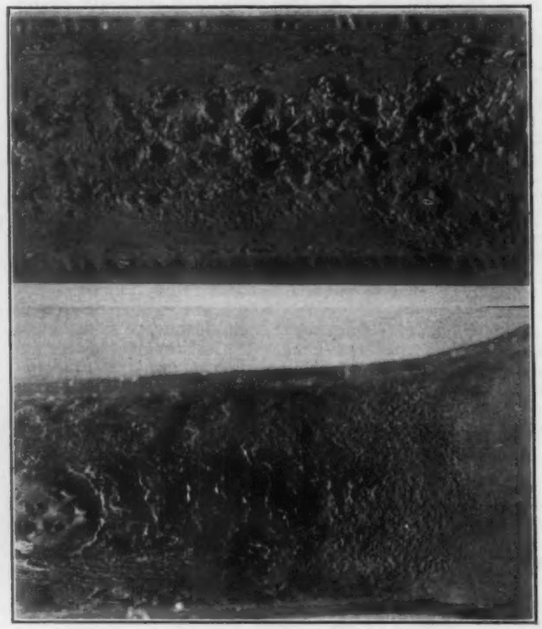


Fig. 13. (Above) A sample from the middle of a tube from No. 9 condenser, second pass, west section. Operation started July 10, 1926, tube removed for inspection (no leaks) Nov. 1, 1927. (Below) Belled inlet end of a tube from the first pass, east section, No. 9 condenser Long Beach steam plant, showing corrosion at the top of the tube due to air in the water. Operation started July 10, 1926, tube removed Jan. 3, 1928.

pulled out as shown in Fig. 7, and the pitting investigated. The location of the pits and their relative depths are indicated graphically in Fig. 8. It may be seen that the corrosion is most severe on the outside tubes and generally in the middle of the tube between the two tube support sheets. Those tubes that are farthest away from any electrodes have the worst pitting. On horizontal Row 14, which extends from an electrode to the outside of the tube bundle, the tubes nearest the electrode show no pitting.

TABLE III—Chemical Analysis of Black, Green and Brown Deposits Found on Condenser Tubes at Long Beach Steam Plant.

Material	Brown Deposit (per cent)	Green Deposit (per cent)	Black Deposi (per cent)
Moisture (loss at 105°)	5.1	5.3	6.7
Organic and volatile matter	12.3	19.0	25.3
Insolubles (silica, etc.)	1.9	8.1	11.7
Copper (Cu)	52.8	20.9	22.0
Zinc (Zn)	11.6	24.0	7.6
Iron oxide (Fe_3O_4)	3.1	2.1	13.8
Calcium (Ca)	0.9	0.6	1.4
Sulphates (SO_4)	0.4	3.2	2.3
Chlorides (Cl)	1.3	2.8	5.7

Two outside tubes from this condenser are shown in the photographic collection which is a part of this report. Tube No. 1, Row 56, which was removed after nine months service has a corroded area a few inches long, but corrosion is deep enough to cause a leak. Tube No. 1, Row 55, an adjacent tube, has a corroded section that is several feet long, after 17 months service. Evidently the corrosion spreads and eventually

TABLE IV—Condenser Tube Deposits Calculated on Dry Basis.

Material	Brown Deposit (per cent)	Green Deposit (per cent)	Black Deposit (per cent)
Organic and volatile matter	13.0	20.1	27.1
Insolubles (Silica, etc.)	2.0	8.6	12.5
Copper (Cu)	55.8	22.1	23.6
Zinc (Zn)	12.3	25.4	8.2
Iron oxide (Fe_3O_4)	3.3	2.2	14.8
Calcium (Ca)	1.0	0.6	1.5
Sulphates (SO_4)	0.4	3.4	2.5
Chlorides	1.4	3.0	6.1

will cover the entire length if a tube leak is not developed in the meantime.

Thickness of Tube Deposits

As mentioned in last year's report, the deposits inside the tube consist of a green, hard scale and a layer of mud on top of that. Outside the tube is a black coating of copper oxide. These layers have been measured approximately with a microscope. The green scale is 0.0001 in., the brown layer 0.00016 in., and the

TABLE V—Condenser Tube Deposits Calculated on Basis of Corrosion Products Only.

Material	Brown Deposit (per cent)	Green Deposit (per cent)	Black Deposit (per cent)
Insolubles (Silica, etc.)			18.1
Copper (Cu)	75.4	39.0	34.1
Zinc (Zn)	16.4	44.8	11.8
Iron oxide (Fe_3O_4)	4.4	3.9	21.4
Calcium (Ca)	1.3	1.1	2.2
Sulphates (SO_4)	0.6	6.0	3.6
Chlorides (Cl)	1.9	5.2	8.8

black deposit 0.00005 in. The tube shows a content (by analysis) of 71.5 per cent (copper, 27.1 per cent) zinc, and 1.4 per cent tin.

Chemical analysis of the brown, green and black deposits shows them to be composed as given in Table III.

Liquid and Gaseous Fuels*

Studies of the subcommittee on burning of liquid and gaseous fuels is confined to the mechanical atomizing type of oil burners as very little of interest on the steam atomizing type can be brought up at this time, developments having made this equipment obsolete. Work is carried on in as close harmony with the national committee as possible in order to contribute Pacific Coast experiences and developments as to liquid and gaseous fuels.

Advice from R. C. Powell of the Pacific Gas and Electric Company showed that the N.E.L.A. prime movers committee is studying this year only one subject, the means of handling the returned oil from wide range burners. In addition, however, there is some interest in high-pressure gas burners.

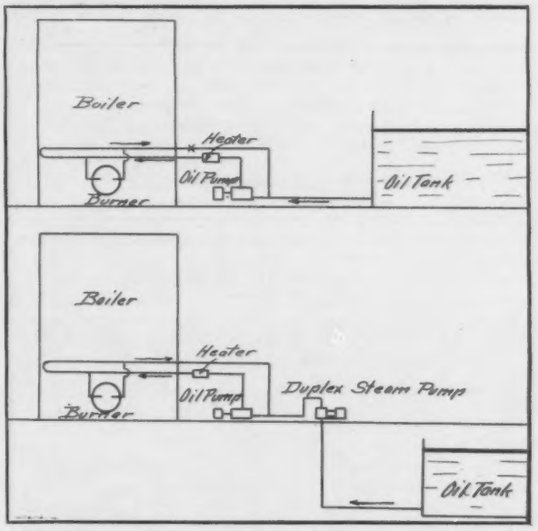


Fig. 1. (Above) A method used on the Atlantic Coast to care for returned oil from wide-range oil burners. The tank is above the ground furnishing sufficient pressure for the oil pump to handle the hot oil at the suction.

Fig. 2. (Below) Another Atlantic Coast installation where the tank is underground and the pressure is furnished by a duplex steam-driven pump with governor set to maintain a 5-lb.-per-sq.-in. pressure on the main oil pump suction.

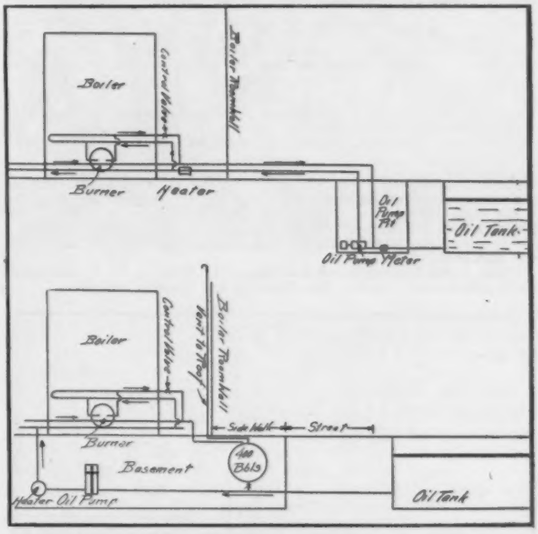


Fig. 3. (Above) Method of handling returned oil from wide-range burners at the Pasadena municipal steam plant.

Fig. 4. (Below) Method used by San Diego Consolidated Gas and Electric Company to handle returned oil from wide-range burners. In this case manual control is required to handle the oil from the return tank to the pump suction.

The six methods shown of handling the returned oil have been in operation in different installations with satisfaction, we are assured by the manufacturer, from whom we quote on the subject:

You will be interested to know that trouble with wide-range return oil is another West Coast problem as we do not have this to contend with any place else in the country. This may be because the insurance underwriters or local authorities in California are more stringent in their rulings than elsewhere. We have used two methods both of which have been successful. In the first, Fig. 1, the service pump has taken the oil directly from an overground

* Report of subcommittee of prime movers committee.—R. A. Wallingford, chairman.

storage tank, the hot oil return being fed into the suction of the pump between the tank and the pump. This method is frowned upon by the insurance underwriters in some sections as they do not like to have the overground tank connected directly to the pump without an intervening storage tank underground. We have used this method of installation pretty well along the entire Atlantic Seaboard.

Another method, Fig. II, which we have used, is to place a reciprocating steam pump directly at the (underground) tank with a governor set to maintain a pressure of 5 lb. at the suction-end of the service pump, which generally is located in the boiler house. The hot oil then is returned between the delivery of the steam pump and the suction of the service pump. This, of course, is a very satisfactory method of handling the problem. There is no real objection to having the steam pump at the storage tank, as in most

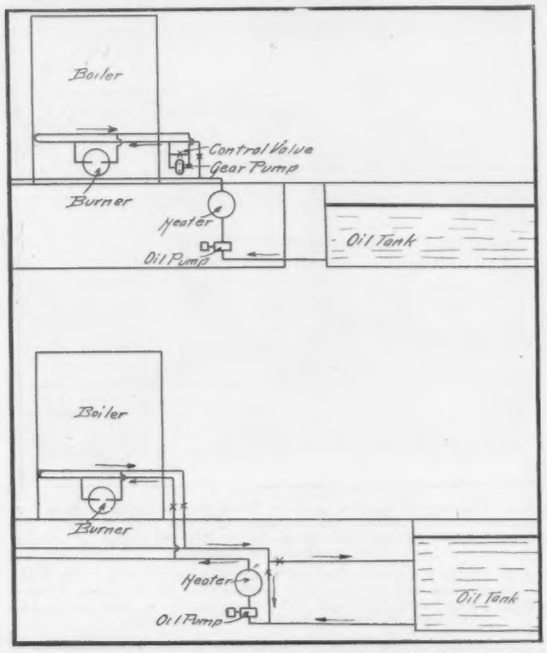


Fig. 5. (Above) Oil handling method in use at the Seal Beach plant of the Los Angeles Gas and Electric Corporation. The gear pump shown runs at constant speed and handles a constant volume of oil. Burner control is effected by operation of the bypass valve as indicated.

Fig. 6. (Below) Oil-handling method at the Long Beach No. 3 plant of the Southern California Edison Company. With this system the returned oil can be returned to the suction of the oil pumps or to the oil tank as desired.

cases it is necessary to supply steam to the tank to handle the oil and this may be obtained readily from the exhaust of the pump.

We have looked into the use of heat exchangers and find they are not very efficient on oil to oil, and to get a heat exchanger which would cool the return oil sufficiently would be prohibitive in cost and size.

Other methods mentioned are shown in Figs. 3 to 6, inclusive, which are merely one-line diagrams of the general schemes.

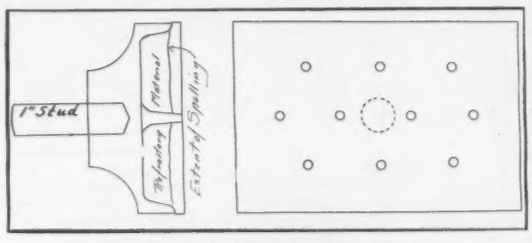


Fig. 7. A type BA block.

Mechanical Atomizing Oil Burners

Very little has come to the attention of this committee that is worthy of report. Manufacturing companies reporting have had nothing new to report and the same is true of the operating companies.

At the Long Beach No. 3 Plant, insulated front, combination gas-and-oil burners are to be installed. Aside from this insulated front no noteworthy improvements in oil or gas burning equipment has come to attention.

At the January, 1928, meeting this subcommittee mentioned some experimental work that had been carried on at the Long Beach Steam Plant No. 2 with the idea of obtaining wider range of operation without sacrifice of efficient atomization or the difficulties encountered in returning hot oil from the burners. No further work has been done on this and there is nothing more to report on them except that they have been in more or less successful operation most of the time since.

Furnace Maintenance

Contributions on this subject are confined to but one of the member companies, all others having failed to respond.

At the Long Beach No. 2 Plant of the Southern California Edison Company, water-cooled walls are in use on the fronts and sides of 7 of the 15 1,500-hp. boilers.

Blocks used on these walls are the manufacturer's type B. A., Fig. 7, constructed of cast iron and refractory-faced, the refractory being 1¼ in. thick protruding ⅜ in. in front of the edges of the blocks. Fusing and spalling of this refractory face progressed slowly at first, but later when the character of the plant load changed to one of greater irregularity, they began to chip off at the corners and edges and with the use of oil fuel in larger quantities, shallow fusing commenced.

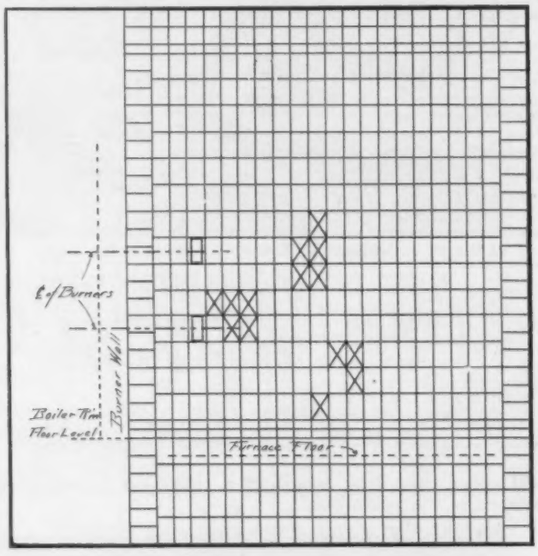


Fig. 8. Side wall block diagram showing location of blocks that failed, west wall No. 46 boiler, Long Beach steam plant.

Progressive fusing and spalling took off the face to approximately the depth of the protrusion beyond the metal part of the blocks. Here, however, it seemed to stop and further progress has been very slow except in rare instances.

Block failures have been scarce and the few that have occurred were repaired easily by replacing with new blocks. With but one exception, all failures have been of single blocks remotely separated from each other. The exception is worthy of mention.

On January 25, 1928, after 4,322 hours of operation with natural gas fuel and 2,595 hours operation with oil, inspection of the furnace revealed the fact that a number of wall blocks in both the west and east walls were badly burned. With but one exception the burned blocks were in direct line with the two rows of burners in the front furnace wall, Figs. 8 and 9, and it was natural to lay the responsibility to a dirty burner, causing flame impingement against the wall at these points. However, upon removing these blocks for replacement it was found in each instance that the spring washer used in clamping the block to the tubes was broken and had left the bond between block and tube in a poor condition. Thus the burners were exonerated, at least in part. A number of blocks were inspected on other boilers as they were brought down for general cleaning and repairs, but no more broken washers were found. It later was brought out that a special stainless steel washer was tried out on this one boiler at the time of installation. No further trouble is developing apparently. Tubes at the location of the burned blocks were not distorted or injured, and repairs were simply and easily made.

Figure 10 shows general appearance of the west wall, and Fig. 11 shows a close-up view of the affected groups.

Refractories deteriorate very slowly under gas burning conditions and with a steady load their life would be indefinite. However, fluctuations in load sufficient to cause cutting a boiler into and out of service results

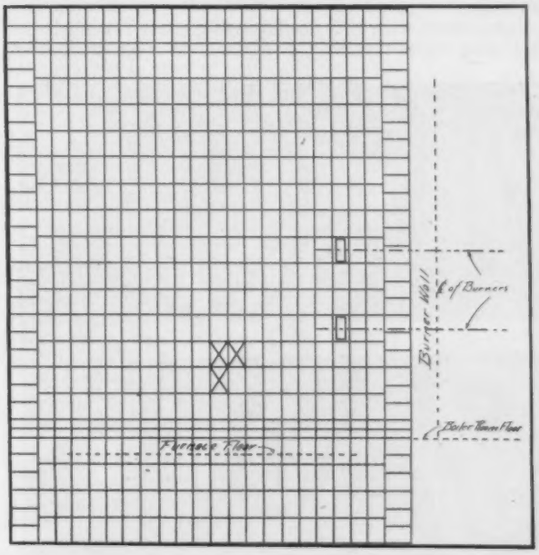


Fig. 9. The same as Fig. 8 for the east wall.

in more or less spalling. Oil burning causes rapid deterioration of brick work, due apparently to sodium sulphate either contained in the oil or formed during combustion by the combination of the sulphur content of the oil with the sodium chloride in the moisture content. In either case the result is the same.

Oil company chemists are of the opinion that sodium sulphate found deposited on the outside of boiler tubes and which is assumed to be the cause of fluxing of fire brick comes from the water present in the oil, as the moisture content from most wells carries considerable

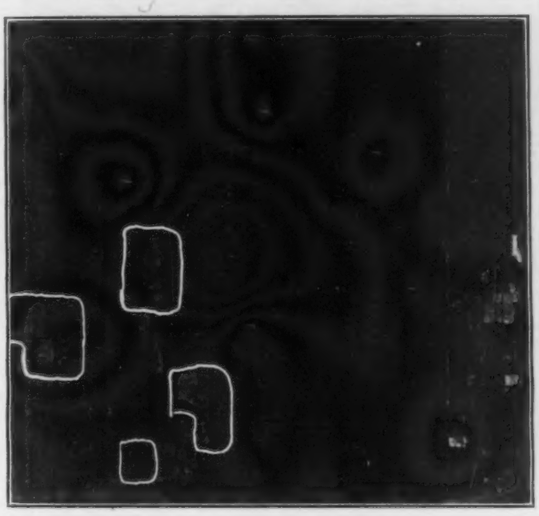


Fig. 10. A photographic record of the west wall showing burned-out blocks.

of this product. In fact the water analysis is used as a means to determine the strata from which the oil is being drawn. Water found with most California oils carries considerable sodium sulphate. The Huntington Beach field is probably the only one especially free from it.

Fuel oil used at Long Beach is taken principally from three fields, proportioned about as follows: 60 per cent from Dominguez, 25 per cent from Richfield District, including Santa Fe Springs and Coyote wells, and 15 per cent from the Huntington Beach field. The crude stock first is treated cold in dehydrators of the electric type to remove as much moisture as possible and then in the stills where one large "cut" is made which later is treated as refinery stock through the various processes. The remainder is the fuel oil furnished here. No residue from the refining process is included in the fuel oil and though acid treatment is used in some of the refining processes and later neutralized by lime, none of this product is included with the fuel oil.

Corrosion occurs in the condensation process, after the stills, and some oil companies use soda there as a preventive, but this occurs after the crude is separated. A complete photographic record is kept of the condition of furnace refractories and the water-cooled walls, a series of six photographs being made each time a boiler is brought down for repairs.

Boilers brought off the line for repairs are thoroughly inspected and recommendations made. Brick sufficiently bad are replaced. All refractories except the water-cooled walls then are given a coat of refractory wash made up of Hytempite, fire clay and a grog made of ground-up brickbats. This is applied with the aid

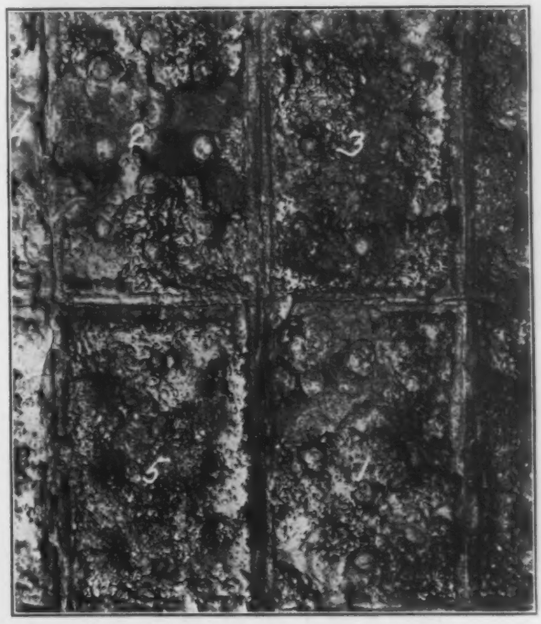


Fig. 11. A close-up of burned-out blocks.

of a refractory gun and smoothed over with a trowel, the deeper cavities having been rammed full of a plastic mixture previously to make a fairly uniform surface to shoot at.

Amounts used per boiler run somewhere between the following limits: for thin coats 125 lb. Hytempite, 100 lb. mission mortar (fire clay), 250 lb. grog; and for heavy coats, 200 lb. Hytempite, 100 lb. mission mortar, 500 lb. grog.

Care is taken to see that all cleaning or other work that will knock down dust from the tubes or other parts of the boiler onto brick work has been completed before any wash has been put on the walls. Dust and accumulations from the tubes is largely sodium sulphate and seems to act as a flux on the hot refractories.

Tests for Relative Capacities of Oil Burners At Long Beach Steam Plant No. 2

Regulation of oil fires in a furnace usually is considered to be a simple matter of opening or closing a valve to increase or decrease the flow of oil, and the proper adjustment of the draft pressures, etc. However, regulation of the fires between the several burners of a furnace containing a number of burners by no means is that simple. Usually it is assumed that burners are uniform and pass equal amounts of oil. It sometimes is perplexing to note the difficulty of obtaining good combustion without a large excess of air.

At Long Beach No. 2 attention was called to the fact that assumptions of perfection and uniformity were without foundation of fact. The truth was that there was an actual extreme variation in the amount of oil passed by individual burners of as much as 30 per cent. Also, it was found that new precision parts from the manufacturer varied considerably and in a few cases were as much as five per cent above or below the average, although a large majority were well within two per cent. Assuming that the parts tested were representative of the general run of their kind, 2 per cent

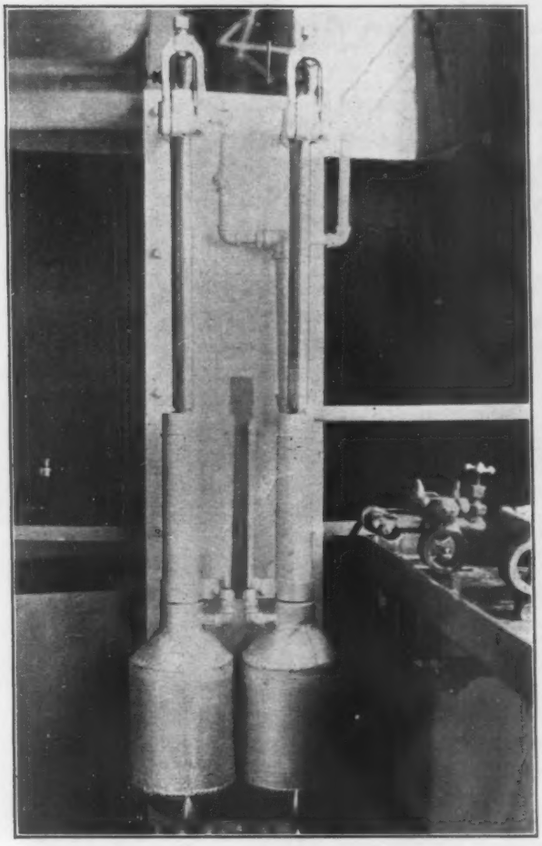


Fig. 12. (Above) Oil burner tester fitted with a burner to be tested against a "standard" burner.

was taken as an arbitrary limit of tolerance, either above or below the accepted standard. The matter of how this variation of capacity was found and the simple and accurate method and apparatus used, also the incidents leading up to its inception, are described in the following.

At Long Beach all of the mechanical atomizing oil burners used are kept at uniform capacity by the acid of an apparatus extremely simple in construction and operation. There are no working parts. It cannot wear out and is easily kept in calibration.

There were several steps leading up to the present method of testing burner tips and the apparatus used is the natural out-growth of these.

For a long time burners were judged as to their condition for use by the eye only, the uniformity, smoothness, and fineness of the water spray from each individual burner at the repair bench were the only qualifications taken into consideration unless the quantity or the angle of the spray were flagrantly wrong. How great a variation could be overlooked may be judged from photographs which show our new two-capacity burner spraying water at its high and low ranges, the latter of which is but 65 per cent of the former yet the difference is scarcely discernable.

With the advent of the new burners just mentioned it was desired to test them for comparison with the burners then in use, and for uniformity of capacity. The first method tried consisted of muzzling the discharge end with a cloth tied loosely over it to collect the water and allow it to fall into a bucket or other measuring vessel. The bucket used was taken as an arbitrary standard and the time required to fill it to overflowing was determined with a stop watch. Comparative capacities then were calculated from the time values. Obviously it was necessary to maintain a constant pressure on the water supply while taking readings.

Tests made with this crude arrangement revealed the fact that even though the machinists who made the

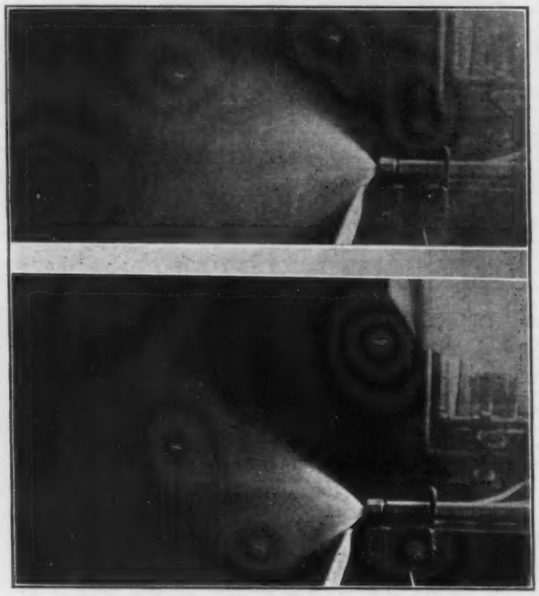


Fig. 13. The burner shown below is passing about 50 per cent more water than the burner shown above although the visible difference is fittle, if any.

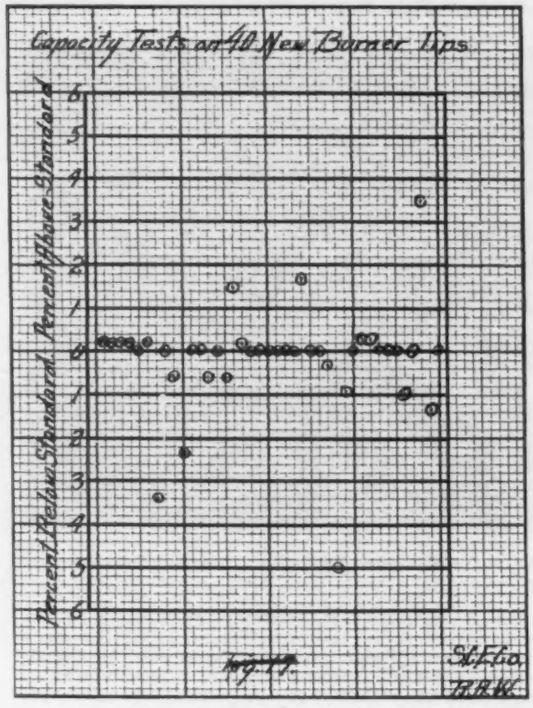


Fig. 14. Results of capacity tests on 40 new burner tips. The average of these readings determines the "standard" used for comparison.

burners worked with the utmost care the results of their labors were far from accurate. There was an extreme variation of more than 20 per cent, about equally divided above and below the average capacity. Considerable work was necessary to bring these within a reasonable degree of tolerance which was set arbitrarily at 2 per cent above or below standard.

Importance of testing all burners in use and of discarding all tips that could not be brought within the set bounds was recognized readily. A standard was established by tests of forty new tips. The result of these tests is shown in Fig. 14.

With the making of such a large number of tests the cloth-bound muzzle was discarded for a more convenient arrangement consisting of two 2-in. nipples screwed into an elbow. This was hung over the end of the burner in position at the repair bench and accomplished the same result, and better.

With this device 165 burners were tested and worked over after removing all foreign matter, burs, etc. Many of them were tested a number of times. After doing all that at that time seemed reasonable to bring the tips to within the established limits it was necessary to discard 48 in all. These all were reclaimed, however, at a later date when it was found to be not only possible, but practicable to deepen the grooves by hand to increase the capacity and to grind down the face of the tips to decrease it.

This work was all done on the night shift and the crude apparatus described was quite satisfactory because steady pressure was maintained easily on the house lines. In the day time, however, it was impossible to maintain constant pressure because of the intermittent use of water from the house lines. For this reason it was thought more practical to test burners by comparing them with a burner of known standard capacity connected parallel with the burner to be tested. Variation in pressure then would affect one as much as the other. It was to accomplish this that the apparatus described here was built.

Of several suggested methods the one selected consists of two iron cylinders each made of a piece of standard 6-in. pipe 8 in. long with a taper at the upper end to a 2-in. nipple about 18 in. long, forming a neck of this length the capacity of which is approximately 13 or 14 per cent of the whole. The bottom is tapered to a ¾-in. nipple and a quick-opening valve attached for a drain. The two bottles or cylinders are identical in size and are mounted on a sheet iron plate or panel side by side. The panel is 12 in. wide and long enough to accommodate these and the two burners in such relationship to each other that the discharge ends of the latter just enter the open ends of the necks of the former. The burner mountings are supplied with water through a tee connection from a common source and water to them is controlled by a single quick-opening valve. Fittings are of liberal size to insure full line pressure to the burners. Under the whole assembly is a funnel which catches the water drained from the ¾ in. valves at the bottom.

Calibration of the bottles was made in the following manner: One was filled with water to a point about half-way up the neck and a mark made on the brass scale between the two gage glasses. The water then was transferred to the other bottle and its height noted there. Into the bottle shown to be the larger of the two a number of ¾-in. iron washers were dropped until repeated trials of pouring water from one to the other brought the level to the same height in each. This water then was removed and carefully weighed. This weight was divided by one hundred and the hundredth part added to the contents of one of the bottles which had been refilled to the original point, and the rise noted. This rise then was taken as a measure of one per cent and the scale calibrated accordingly. There is a total calibration in the neck of 13 per cent from 93 to 106 per cent of the total contents at the established mark.

The apparatus illustrated originally was of an experimental nature and may not show the very ultimate in workmanship and beauty. Nevertheless, the testing done with it has resulted in great satisfaction through the adjustments made possible. There was a noticeable improvement in combustion conditions after adoption of this method.

It is contemplated that such apparatus built in the future shall be made of brass or other non-corrosive material as corrosion or collection of rust are liable to change the volume and lead to erroneous conclusions. To avoid error from these causes at present the relative volumes are checked from time to time by establishing the relationship between two burners, and reversing their position on the panel to see what difference, if any, exists. Thus far it has not been necessary to make any adjustments on this account.

Measurement of Burner Capacity While in Service

Some mention was made of a system in limited use at Long Beach for measuring the capacity of gas burners while in position in the boiler. The first step toward the solution of this difficulty was the development of a Pitot-tube arrangement to be inserted readily into the 2½-in. piping to the individual burners. This never was used for almost simultaneously came the idea of a more reliable orifice arrangement that could be installed more readily without the necessity of drilling and tapping each burner connection.

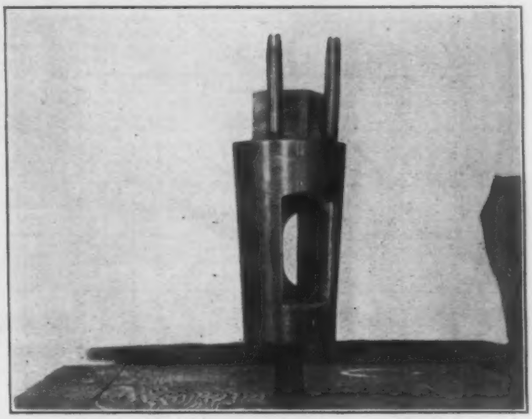


Fig. 15. Looking at gas-plug orifice from downstream side.

Substantially it consists of a straightening chamber for removing eddies likely to be set up by pipe fittings in close proximity on the up-steam side, an orifice with close connections for static and differential readings and two U-tubes for taking pressure readings. The straightening chamber, orifice and pressure connections all are in one piece shaped to fit snugly into the stop-cock in place of the regular plug.

Procedure in taking readings for each burner is as folows: (1) Gas is shut off at header. (2) The plug of the stop-cock is removed and the special orifice plug inserted in its place and made fast. (3) Gas then is turned on from the gas header and as it flows through the orifice to the burner readings are taken from the two U-tubes simultaneously. (4) Gas again is shut off and the regular stop-cock plug put back into place. The burner then is in normal condition and this procedure is repeated with each burner of the set.

It is necessary only to take one set of readings per burner so long as it is reasonably certain that the static and differential pressures are read simultaneously. The relationship between the static pressure applied and the resulting differential is a straight-line relationship and the readings are converted readily to a standard pressure which in this case has been arbitrarily set at 3½ lb. Then, having the differential set-up by gas to each burner at a given pressure it is a simple matter to calculate the quantity of gas passed by each. Sample chart shows result of one set of readings.

It has been found that the greatest cause of variation in burner capacity is due to accumulations of dirt and sand out of the gas, and from carbonization of the oil vapors in the gas. Small cracks in the burner plates, etc., are almost insignificant in their effect upon capacity. Large ones of course show up in increased quantity of gas passed.

By means of this arrangement defective burners can be detected while in service and if bad enough to warrant can be replaced with new ones or removed and repaired at a more convenient time.

Pacific Gas and Electric Company is installing at Oakland a large turbo-generator with two 3,500-hp. boilers with cooled walls and floors, using large air preheaters and no economizers.

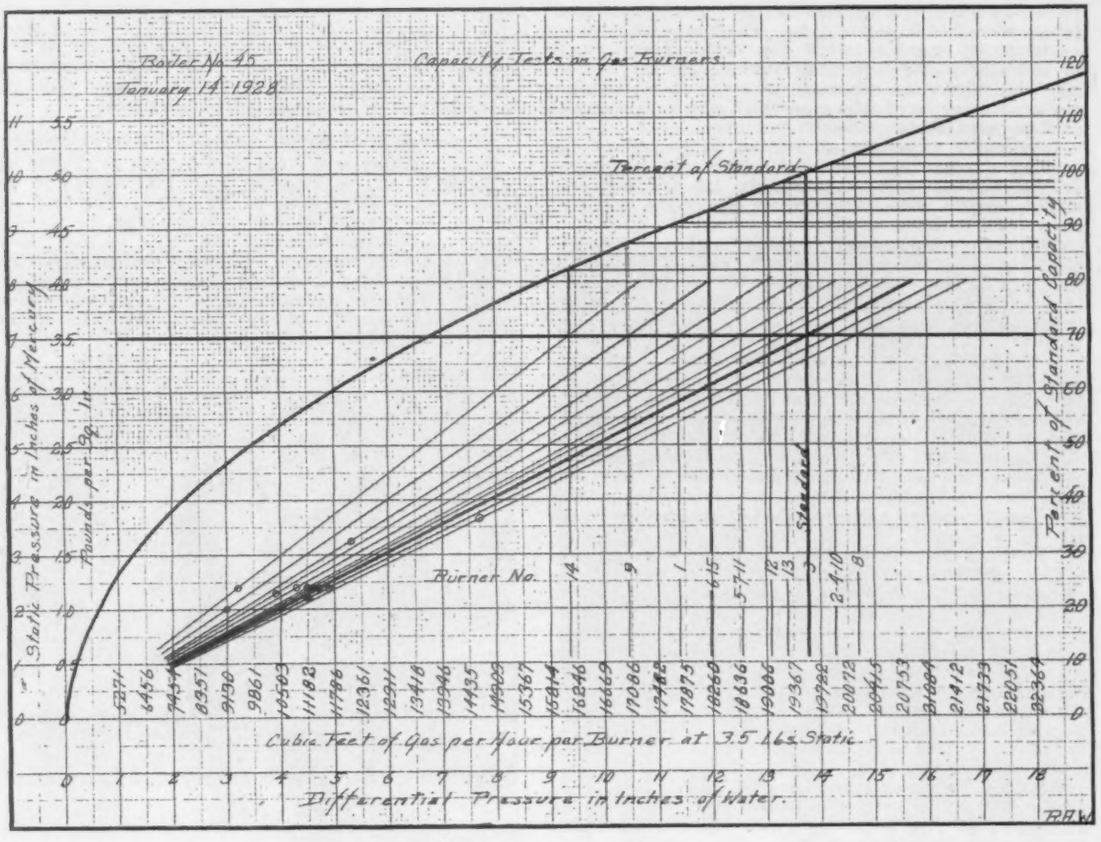

Boiler No. 45
January 14-1928
Capacity Tests on Gas Burners.
Percent of Standard
Percent of Standard Capacity
Static Pressure in Inches of Mercury
Pounds per Sq. In.
Burner No.
Standard
Cubic Feet of Gas per Hour per Burner at 3.5 Lbs. Static.
Differential Pressure in Inches of Water.
F.B.W.

Fig. 16. Capacity tests on gas burners.

The Southern California Edison Company is installing at Long Beach a 94,000-kw. turbo-generator supplied with steam from three 3,400-hp. boilers equipped with air pre-heaters, water-cooled walls and no economizers.

Another idea used by this same company is the system of taking a standard set of photographs of each boiler fire-box as the boiler comes down for general repairs and repairing. By this system a complete visual record is always on hand, showing progressive deterioration of brick work, etc.

New Installations

Los Angeles Gas and Electric Corporation is installing at Seal Beach a 35,000-kw. turbo-generator with three 2,500-hp. boilers with air pre-heaters and no economizers.

Pasadena Municipal Light Plant is installing a 20,000-kw. turbo-generator that will be supplied by two 1,500-hp. boilers.

A canvass of the Pacific Gas and Electric Company's stations in the vicinity of San Francisco shows that there have been no new installations or noteworthy improvements in the past year and that no experimenting with mechanical atomizing oil burners has been done there.

A method of bringing a plant on the line when called, from a cold stand-by condition, is as follows:

Oil for the burners is heated in a 3½ gal. gas water heater. This also heats atomizing air which is taken from a motor-driven air compressor. Oil is pumped by a duplex pump driven by air. When steam is up to about 75 lb. the air is shut off and steam is used for atomizing and pumping.

Steam Plant Maintenance and Repair*

During the year 1927 five Pacific Coast companies began the installation of additional steam plant capacity utilizing modern equipment for heat balance according to the regenerative cycle. These plants all will be in operation during the year 1928 and should provide much interesting data on modern equipment of this kind.

TABLE I—New steam electric installations in the Pacific Southwest, 1927.

Company	Location	Capacity of Unit Kw.	Steam Pres. Temp.	Stages Extraction
Pacific Gas and Electric Co.	Oakland	37,500	425–700	4 Points
Southern California Edison Company	Long Beach	94,000	400–725	4 Points
Los Angeles Gas and Electric Corp.	Seal Beach	36,250	370–725	4 Points
San Diego Consolidated Gas and Electric	San Diego	28,000	225–700	3 Points
City of Pasadena	Pasadena	15,000	410–725	3 Points

Capacities given include auxiliary shaft generator when used.

Steam pressures remain moderate, as fuel costs in this section scarcely warrant added expenditures for higher pressures including the reheat cycle.

Heat balance diagrams are shown in Figs. 1 and 2 for the 35,000-kw. unit of the Pacific Gas and Electric Company and for the 94,000-kw. unit of the Southern California Edison Company. The 35,000-kw. unit will be a single-cylinder machine of nine stages, while the 94,000-kw. unit will be a 21-stage machine with the last three stages arranged for double flow in a second cylinder on the same shaft.

Special Features of Design

The 9-stage unit will be bled at the first, third, fifth and seventh stages for heating the feed water and at the fifth stage for the evaporators. All bleeder lines are equipped with reverse-current valves, protecting the turbine from any back-flow of steam from the heaters in case of a sudden reduction of pressure in the different stages of the machine and consequent flashing of any condensed steam in the heaters. In case of a tube break in the heaters a float is provided at each heater which operates a

* Report of subcommittee of prime movers committee.—L. J. Kraps, chairman.

pilot valve which in turn operates a hydraulic cylinder on the reverse-current valve, closing the valve and holding it closed until the heater is cut out. This same pilot valve also opens a spill valve which discharges the water leaking into the heater to the sewer.

The 21-stage unit will be bled at the fifth, tenth, fourteenth and eighteenth stages, with the evaporators operating from the tenth stage extraction. Provision is made to bring steam direct from the tenth stage extraction line, through a reducing valve, to the evaporator condenser at times when the evaporators are out of service, reducing somewhat the requirements on the tenth stage heater.

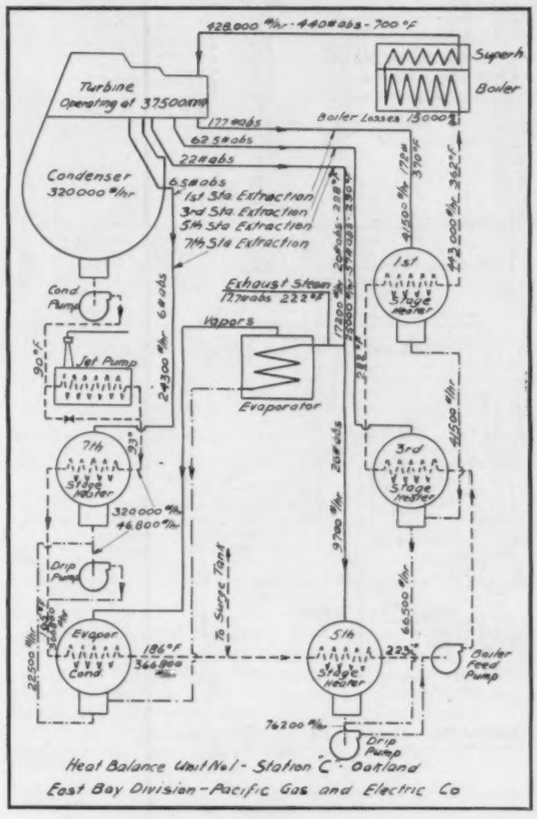


Fig. 1. Heat balance, unit No. 1, Station C, Pacific Gas and Electric Company.

The surge tank has been replaced by a service distilled-water tank near the level of the condenser hotwells, equipped with "make-up" and "draw-off" valves operated by the water level in the hotwells to care for any surges in the condensate line. Reheat hotwells will be provided with steam from the turbine exhaust preventing any under-cooling of the condensate.

Operating Results—Heat Balance

Included in Table II are some very interesting operating results from the Seal Beach Station of the Los Angeles Gas & Electric Corporation. The heat balance of this station employs a very complete recovery of low-grade heat transformer cooling water, generator air coolers and bearing oil coolers, and represents about the limit of economy from four stages of extraction. Turbine room economy of 28 per cent or better frequently is realized both at Seal Beach and at Long Beach in ordinary operation.

Theoretical Heat Balance Calculations

In last year's report calculations and curves were given showing the best points for various combinations of extraction heaters. (See pages 230 to 234, 1927 P.C.E.A. Proceedings.) Once the number and location of heaters are determined for given steam conditions, the fractional-load characteristics also can be determined quite accurately.

Since inlet and intermediate-stage pressures are straight-line functions of the steam passed and proportional to each other, reduction in pressure and flow to the throttling type of turbine being accomplished without loss or gain of heat, the quality of steam, both at the throttle and extraction points for the theoretical turbine can be located on the heat-entropy diagram. These values are proportional to the true values in the actual machine and give the per cent gain from any cycle or combination of heaters. If fractional values of designed or "base" inlet pressures are used instead of load, the calculations will apply to any machine.

TABLE II—Heat Balance for Seal Beach Plant, Los Angeles Gas & Electric Corporation.

	Oct. 30, 1927	Jan. 27, 1928	Jan. 4, 1928
Load in net kw.	12,300	24,000	35,500
Vac., in. abs.	1.07 in. Merc.	1.15 in. Merc.	1.3 in. Merc.
Total steam temp.	655°F.	696°F	700°F.
Steam pressure, lbs. ga	380	375	375
Gas, B. t. u. per cu. ft	1,152	1,122	1,149
CO_2 in flue gas	10%	11%	10.6%
Temp. of circ. water	66°F.	56°F	60°F.
B. t. u. total to turbine	219,268,000	394,458,000	579,275,000
B. t. u. to net kw.-hr.	41,967,600	81,888,000	121,126,000
B. t. u. to hotwell condensate	6,440,000	10,669,000	16,575,000
B. t. u. to auxiliaries	1,978,960	3,412,000	3,412,000
B. t. u. to sea water	115,500,000	190,680,000	274,402,000
B. t. u. fr. trans. cooling water	840,000	908,000	650,000
B. t. u. fr. gen. air cooler	2,380,000	2,497,000	2,925,000
B. t. u. fr. bearing oil cooler	560,000	681,000	650,000
B. t. u. fr. air jet pumps	2,380,000	1,589,000	1,300,000
B. t. u. 100°F. and 200°F. heat exchangers	10,852,000	33,780,000	56,525,000
B. t. u. 55 lb. and 110 lb. heat exchangers	22,386,000	44,370,000	68,042,500
B. t. u. to not acct. for	13,983,440	22,724,000	33,666,000
B. t. u. to storage water		1,260,000	
B. t. u. total in fuel	201,486,000	353,155,000	520,415,421
B. t. u. per kw.-hr.	16,380	14,715	14,660
B. t. u. from preheater	8,654,000	15,299,388	22,859,074
B. t. u. from furnace walls	3,662,427	7,185,389	8,533,088
B. t. u. to dry gas	5,642,240	12,813,676	23,992,591
B. t. u. to wet gas	21,009,450	38,400,100	56,453,070
B. t. u. to radiation, other losses	1,404,310	717,214	7,362,260
Boiler efficiency	86.0%	85.3%	83.1%
Thermal efficiency	20.8%	23.2%	23.2%
Turbine-room efficiency	24.2%	27.2%	28.0%

Note:—October 20, 1927, two jet air pumps on. January 27, 1928, evaporators on.

In Fig. 8, page 233 of the 1927 Proceedings, the most economical temperature for 3-stage bleed for steam conditions of 350-lb. gage, 700 deg. F. and 1-in. mercury (abs.) back pressure is given as 360 deg. F. or 153 lb. abs. from the last heater, with approximately equal temperature drop between the three heaters, giving 266.4 deg. F., 39.19 lb. abs. and 172.7 deg. F., 6.28 lb. abs. as base temperatures and pressures at the intermediate and low pressures.

Fractional values of these quantities are plotted in Fig. 3 and are used with corresponding values of inlet pressure to determine the quality of steam at each extraction point. Fig. 4, based upon these values, shows the heat available for heating and work from a pound of bled steam at fractional loads.

Fig. 5 shows a diagram of the arrangement of heaters considered, while theoretical values for water rates and B.t.u. used in the turbine cycle are shown in Fig. 6.

In Fig. 7 the gain in economy and loss in capacity due to extraction are shown plotted against quantity of steam or inlet pressure.

Sample calculations for 50 per cent and 100 per cent of base steam flow are given in Table III.

Frequently, because of overload or other reasons, one or more heaters may be taken out of service. Calculations and curves are included showing the gain in capacity and loss in economy when operating under these conditions.

Practically all new plants use the regenerative cycle, where boiler feed-water heating is accomplished by bleeding steam from the main unit. To secure the greatest efficiency from this system, electric-driven auxiliaries are required. Electric drive has proved popular not only because it fits well with the heat-balance system, but also because it is simple and reliable, easy to control, and requires little maintenance.

Many systems have been developed and considerable experience gained using various types of equipment and sources of power. Figures 8 to 13 show some of the different methods of supplying auxiliary power.

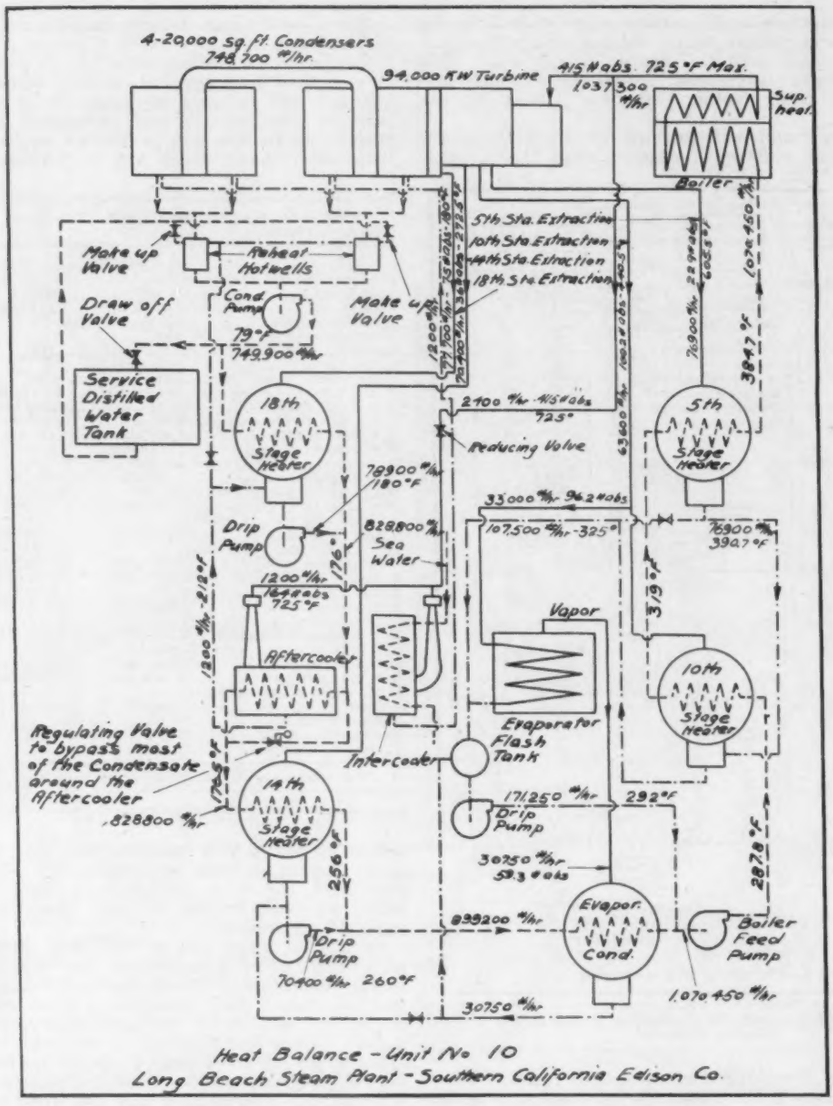


Fig. 2. Heat balance, unit No. 10, Long Beach steam plant, Southern California Edison Company.

Auxiliary Power Supply

The selection of a source for auxiliary power is governed by several factors. First, is the purpose of the station. The expenditure warranted for base-load units may not be justified in a stand-by station. Next, is the type of load. System power through transformers is ideal for auxiliaries where the system is basically stable with several large closely-joined plants operating in parallel. But it cannot be relied upon in Western stations that serve long transmission systems in parallel with distant hyro-electric plants.

Pacific Coast steam plants are called upon to operate alternately for base-load and stand-by service. For the former, a continuous supply of power is needed, while for the latter a supply that is not effected by system disturbances is imperative. This is evident from the characteristics of centrifugal pumps showing that the output drops off many times as fast as the speed. Some pumps have very flat curves and it is not impossible to have a boiler feed pump shut a station down with a drop of 10 per cent in system frequency. This, of course, is intolerable on systems where frequency drops and voltage surges are inevitable with trouble on the long lines to other parallel plants.

Available power sources are: system power, shaft generators, and separate generators. System power is the economical choice and also the simplest and most rugged. In the East it is used extensively with a few dual steam-electric driven units in the station, but Western system disturbances are too many, and where it is used it must be supplemented with a separate generator capable of instantly taking all of the load.

A shaft generator is economical in all but floor space and frees the auxiliary power from all system disturbances except low frequency. It must, therefore, also be supplemented with a separate generator in stand-by stations. A separate turbo-generator is the most independent of system disturbances. It is so uneconomical though, that continuous operation cannot be justified without extreme complications being taken to use its exhaust steam for feed-water heating and even this is of little avail unless part of the load can be shifted to system power when the demand for exhaust steam decreases.

Direct current with storage battery stand-by and other auxiliary power arrangements might be discussed, but the complications become so great as often to undo their intended reliability.

In conclusion, it would seem that all large and important units should have shaft generators to free their auxiliary power from the system at all times and have in addition a separate turbo-generator instantly to take the load at times of heavy station overload and low frequency. On less important units system power is satisfactory to replace the shaft generator but still should have the stand-by house generator. For simplicity and the reliability that goes with the very word, it is well to recognize that

TABLE III.—Heat Calculations for Three-Stage Extraction System, 365 lb. abs. 700°F.

Item	Without Extraction:	Per cent of Base Steam Flow to Turbine 50%	100%	50%	100%	50%	100%
1.	Pressure at turbine inlet, lb. abs	182.5	365.0	.....	.....	.....	.....
2.	Total heat of steam at turbine inlet, B. t. u. per lb., from H.-E. diagram.	1,364	1,364	.....	.....	.....	.....
3.	Heat at turbine exhaust, B. t. u. per lb., from H.-E. diagram	927	886	.....	.....	.....	.....
4.	B. t. u. per lb. converted to work from throttle to condenser. (2)-(3)	437	478	.....	.....	.....	.....
5.	Water rate, lb. per kw.-hr., steam to condenser. 3,415/(4)	7.815	7.144	.....	.....	.....	.....
6.	Heat of liquid at hotwell, B. t. u. per lb., steam table	47	47	.....	.....	.....	.....
7.	Heat supplied by boiler, B. t. u. per lb. (2)-(6)	1,317	1,317	.....	.....	.....	.....
8.	Heat consumed in turbine cycle, B. t. u. per kw.-hr. (5) x (7)	10,292	9,409	.....	.....	.....	.....
	With extraction.	(Low Pressure heater)		(Intermediate heater)		(High Pressure heater)	
9.	Pressure, lb. abs., steam to heater	3.392	6.283	19.84	39.19	76.75	153
10.	B. t. u. per lb., steam to heater, from H.-E. diagram	1,035	1,024	1,152	1,148	1,267	1,265.75
11.	Heat drop to heater, B. t. u. per lb. (B. t. u. to work) (2)-(10)	329	340	212	216	96.5	98.25
12.	Temperature of water to heater, deg. F	79	79	146.4	172.7	227.5	266.4
13.	Temperature of water from heater, deg. F	146.4	172.7	227.5	266.4	309.2	360.0
14.	Heat of liquid, water from heater, steam table	114.4	140.7	195.5	234.4	277.2	328.0
15.	Heat of liquid, water to heater, from steam table	47.0	47.0	114.4	140.7	195.5	234.4
16.	B. t. u. added per lb. of water through heater. (14)-(15)	67.4	93.7	81.1	93.7	81.7	93.6
17.	Lb. of water to heater per lb. to condenser. (23 for previous heater)	1	1	1.073	1.106	1.164	1.219
18.	B. t. u. absorbed in heater per lb. to condenser. (16) x (17)	67.4	93.7	87.04	103.6	95.12	114.1
19.	B. t. u. available to heat water per lb. steam bled. (10)-(14)	920.6	833.3	956.5	913.6	990.3	937.75
20.	Lb. steam bled to heater per lb. to condenser. (18)/(19)	0.073	0.106	0.091	0.113	0.096	0.122
21.	B. t. u. to work per lb. to condenser from bled steam. (20) x (11)	24.08	36.04	19.29	24.41	9.26	11.96
22.	Theoretical kw.-hr. by steam bled per lb. to condenser. (21)/3415	0.0071	0.0106	0.0057	0.00715	0.0027	0.0035
23.	Lb. water to next heater per lb. to condenser. (17)+(20)	1.073	1.106	1.164	1.2194	1.260	1.3411
	Economy from full and partial extraction.	(Full extraction, three stages)		(Low and intermediate heaters only)		(Low pressure heater only)	
24.	Lb. steam to throttle per lb. to condenser. (23) for combination used	1.260	1.3411	1.164	1.2194	1.073	1.106
25.	B. t. u. to work per lb. to throttle from steam going to condenser. (4)/(24)	346.8	346.4	357.4	392.0	407.19	432.19
26.	B. t. u. to work per lb. to throttle from steam going to L. P. heater. (21 L. P.)/(24)	19.11	26.37	20.69	29.56	22.44	32.59
27.	B. t. u. to work per lb. to throttle from steam going to I. P. heater. (21 I. P.)/(24)	15.31	18.26	16.57	20.03	.....	.....
28.	B. t. u. to work per lb. to throttle from steam going to H. P. heater. (21 H. P.)/(24)	7.35	8.92	.....	.....	.....	.....
29.	Total B. t. u. to work per lb. to throttle (25)+(26)+(27)+(28)	388.57	410.43	412.66	441.58	429.63	464.78
30.	Water rate when bleeding lb. per kw.-hr. 3415/(29)	8.789	8.323	8.275	7.733	7.948	.7.347
31.	Percent of loss in output when bleeding. 100—[(29)/(4) x 100]	11.083	14.4	5.581	7.62	1.687	2.77
32.	Heat consumed in turbine cycle, B. t. u. per lb. (2)—(14) for last heater.	1,086.8	1,036.0	1,168.5	1,129.6	1,249.6	1,223.3
33.	Heat consumed, B. t. u. per kw.-hr. (32) x (30)	9,554	8,622	9,669	8,735	9,932	8,991
34.	Percent of gain in economy. 100—[(33)/(8) x 100]	7.171	8.365	6.054	7.164	3.498	4.440

no large system operates without sufficient capacity to allow the loss of its largest generator for at least a short time. On this basis, all auxiliaries should be grouped to correspond to the main generating unit and have separate power sources for each. Then in each group the number of spares and alternate connections may be reduced to a minimum and yet have the auxiliary system more reliable than the main unit and its power connections.

Special Features of Auxiliary Drive in New Plants

In the new station of the Pacific Gas and Electric Company, auxiliary power supply will be taken from

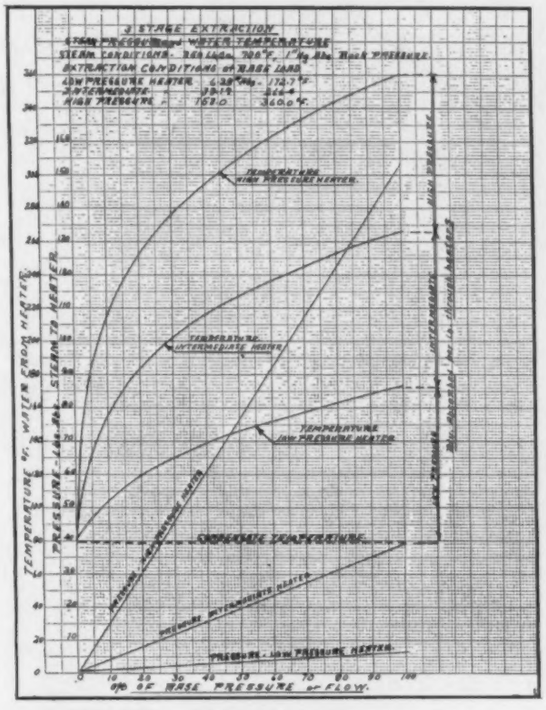


Fig. 3. Three-stage extraction showing steam pressures and water temperatures.

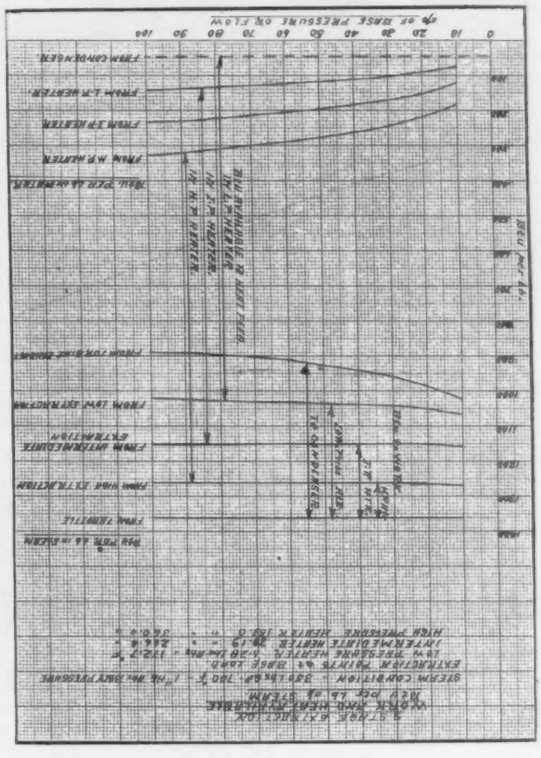


Fig. 4. Three-stage extraction showing work and heat available, B.t.u. per pound of steam.

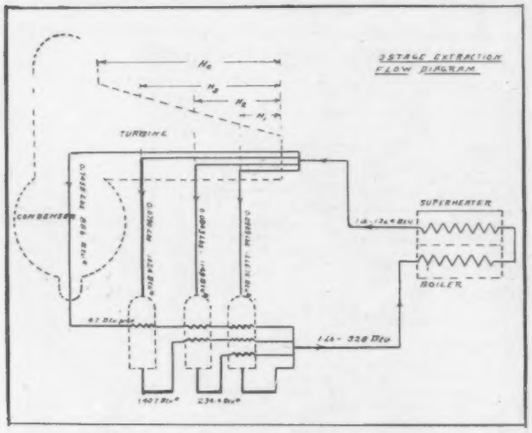


Fig. 5. Three-stage extraction flow diagram.

the main 11-kv. buses and stepped down to 2,300 and 230 volts. Automatic throw-over switches will insure auxiliary supply except in the event that both 11-kv. main station buses are out. Direct current is used for automatic combustion control and power for the motor-operated valves and is furinshed by a 25-kw. steam-electric dual-drive set.

Each boiler is equipped with one forced and one induced-draft fan. Each forced-draft fan is driven by two standard constant-speed squirrel-cage motors (400 and 150 hp.) and the induced-draft fans by two motors of the same kind (400 and 210 hp.) The

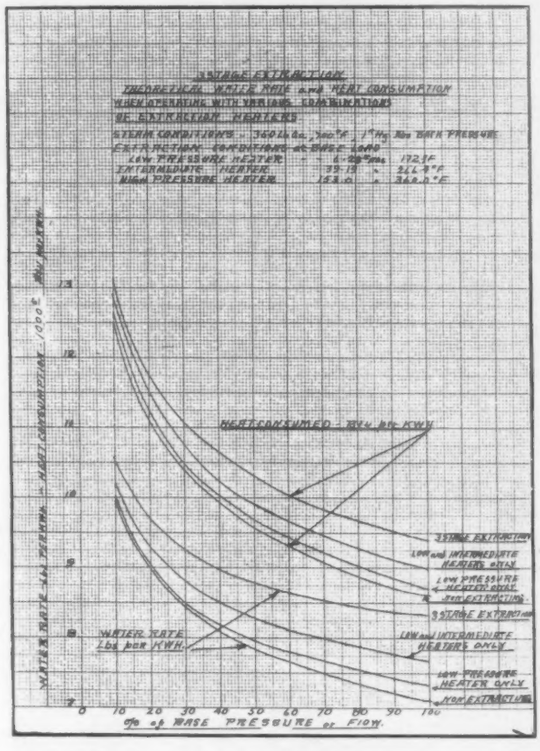

3 STAGE EXTRACTION
THEORETICAL WATER RATE and HEAT CONSUMPTION
WHEN OPERATING WITH VARIOUS COMBINATIONS
OF EXTRACTION HEATERS
STEAM CONDITIONS - 350 Lbs. Gage, 700°F, 1" Hg Abs BACK PRESSURE
EXTRACTION CONDITIONS at BASE LOAD
LOW PRESSURE HEATER - 6.28 Lbs - 172.1°F
INTERMEDIATE HEATERS - 39.19 " - 244.4°F
HIGH PRESSURE HEATER - 153.0 " - 366.0°F
HEAT CONSUMED - BTU's per KWH
3 STAGE EXTRACTION
LOW and INTERMEDIATE HEATERS ONLY
LOW PRESSURE HEATER ONLY
NON EXTRACTION
WATER RATE - Lbs per KWH
% of BASE PRESSURE or FLOW

Fig. 6. Three-stage extraction with theoretical water rate and heat consumption when operating with various combinations of extraction heaters.

larger motors will run at 700 r.p.m., the 150-hp. at 575 r.p.m., and the 210-hp. at 490 r.p.m. These motors are to start by throwing directly across the line at full voltage.

The capacity of the fans is changed automatically by a control. This is accomplished by varying the position of inlet vanes with, say, the larger motor operating at its constant speed until a certain quantity of air is reached. Then the vanes automatically are reset wide open and the larger motor is switched off and the smaller, lower-speed motor is switched on and then any further decrease in air will be taken care of by the vane adjustment. This works out to be a very simple arrangement and the costs are considerably less than other types of control that were given consideration.

At Long Beach steam plant the very exacting service requirements made it desirable to supplement the usual shaft generators with an independent source of auxiliary power and an auxiliary turbine generator is being installed for use only during times when the system frequency is below normal.

Auxiliary Shaft Generator

The auxiliary turbine-generator is a horizontal, single-stage, single-cylinder, single-flow, impulse-type, steam turbine direct connected to a generator having a normal sating of 3,125 kva., 80 per cent power factor, three-phase, 50-cycle, 2.3-kv., 3,000 r.p.m., with a 30-kw., 250-volt, direct-connected exciter on the same shaft.

It will be operated normally as a "standstill" unit with an open ventilation system for the generator. No air coolers will be installed at this time. This turbine-generator is being manufactured with provisions for operating this unit in the future, if desired, normally as a synchronous condenser floating on the 2.3-kv. auxiliary bus. Space is available for the installation of a closed ventilation system if desired in the future.

Starting

A steam-driven auxiliary lubricating-oil pump will be used for starting this auxiliary turbine-generator. This pump will be equipped with a solenoid-operated throttle valve which is to open when energized. It will be controlled by a control relay mounted adjacent to the valve. This control relay will be operated either from the control switch on the main switchboard or from one on the turbine gage board.

Lubricating oil then will be pumped to the bearings, governor and throttle-valve hydraulic operating mechanism. This hydraulic mechanism then will open the throttle valve automatically. It is expected that the steam-driven lubricating-oil pump will build up full pump pressure in eight seconds and full load will

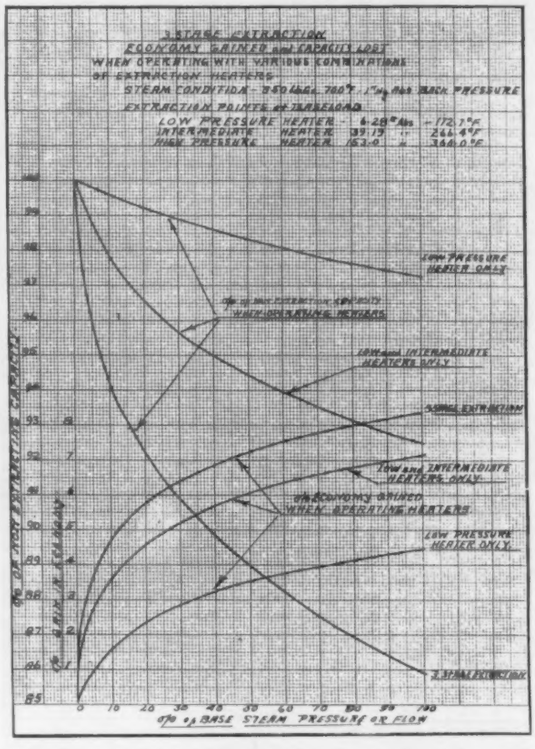
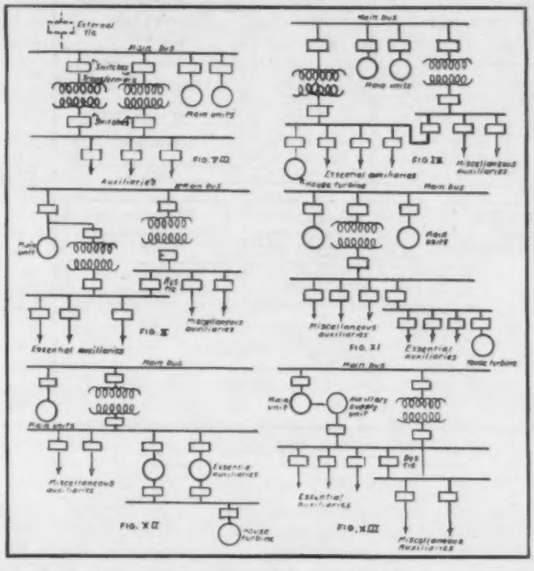

3 STAGE EXTRACTION
ECONOMY GAINED and CAPACITY LOST
WHEN OPERATING WITH VARIOUS COMBINATIONS
OF EXTRACTION HEATERS
STEAM CONDITIONS - 350 Lbs. Gage, 700°F, 1" Hg Abs BACK PRESSURE
EXTRACTION POINTS at BASE LOAD
LOW PRESSURE HEATER - 6.28 Lbs - 172.1°F
INTERMEDIATE HEATER - 39.19 " - 244.4°F
HIGH PRESSURE HEATER - 153.0 " - 366.0°F
LOW PRESSURE HEATER ONLY
LOW and INTERMEDIATE HEATERS ONLY
3 STAGE EXTRACTION
LOW and INTERMEDIATE HEATERS ONLY
LOW PRESSURE HEATER ONLY
3 STAGE EXTRACTION
% of BASE STEAM PRESSURE or FLOW

Fig. 7. Three-stage extraction showing economy gained and capacity lost when operating with various combinations of extraction heaters.

be picked up by the turbine-generator fifteen seconds after the push button is pressed. The generator at all times will be under control of its voltage regulator.

As soon as the auxiliary turbine-generator is up to speed and is carrying the auxiliary load, a manually controlled by-pass around the solenoid-operated oil-pump throttle valve will be opened by the turbine operator. He then will de-energize the solenoid by means of the control switch on the turbine gage board and this will cause the valve to close. By this time, lubricating oil will be supplied adequately and at the proper pressure by the main lubricating oil pump which is directly connected to the auxiliary turbine generator shaft. Since it is contemplated that this auxiliary turbine generator will be operated as a standstill unit and its operation will be intermittent, both the steam-driven and the shaft-driven lubricating-oil pumps will operate during the period the auxiliary turbine generator is operating.



Figs. 8-13. Showing different methods of supplying auxiliary power.

Should it be decided to operate this machine as a spinning generator, it would not be desirable to have the steam-driven lubricating-oil pump operating continuously. The shaft-driven lubricating-oil pump normally will operate and should the pressure in the lubricating-oil system fall below approximately 40 lb. per sq.in., the steam-driven lubricating oil pump will be cut in automatically by a regulator. Ordinarily a bypass would not be needed around the regulator, but a bypass is to be installed so as to utilize the steam-driven lubricating oil pump to empty the entire lubricating-oil system into the dirty-oil tanks when this lubricating oil requires purification.

The steam-driven lubricating-oil pump has a capacity of 100 gal. per min. and the shaft-driven lubricating-oil pump 42 gal. per min.

Normal throttle steam pressure to the auxiliary turbine generator will be 400 lb. per sq.in. and 725 deg. F. total temperature and exhausting to atmosphere.

Steam Plant Operating Methods and Personnel*

The success of any industry depends more than anything else upon the organization of its men and the degree of loyalty, respect and team work that can be fostered among all employees. It is believed, therefore, that the work of the subcommittee on steam plant operating methods and personnel is one of prime importance and one which may extend in its influence through all the many ramifications of the public utility business.

This year the committee has confined itself to gathering information from company members concerning plant organization, operating records, stimulating interest in work and employees' welfare.

* Report of subcommittee of prime movers committee.

Plant Organization

An organization diagram of the personnel of a large modern steam plant is shown in Fig. 1, giving the responsibilities of the various members of the force and showing also the tie between the plant organization and the general office organization in charge of steam plants.

A study of the personnel of this plant compared to an older plant with about one-half the installed capacity shows about the same number of men employed per kw. of capacity. The most interesting difference between the modern plant and the older plant is the number of men in the efficiency department. The modern plant has seven men whereas the older plant has only one or two. This indicates the importance of efficiency work, that the new plants are being run scientifically and that economy is the watchword. The modern plant requires fewer firemen but more technically trained men.

One company operating two large steam plants some distance apart combines the organization of the two plants as follows: One superintendent is responsible for the operation of both stations, while there is an assistant superintendent directly in charge of each plant. Furthermore, at each station there is a chief engineer, whereas there is only one chief electric operator and one combustion engineer whose duties are divided between the two plants. On each shift there is a watch engineer who has charge of the turbine and boiler rooms. Each turbine is operated by a steam engineer while an oiler attends to the auxiliaries of these units. In each boiler room a watertender is in charge, and under him are the firemen.

Operating Records

At another plant daily records of all operating data are kept at the plant by the efficiency department. These records constitute enough data such as fuel used, water evaporated, kilowatt-hours generated, pressures, temperatures and power used in the station, that the efficiency of the whole station is known every day as accurately as though under test.

Special records are kept on important apparatus such as boilers, blood heaters, evaporators and condensers. These are records of performance and by watching them carefully from day to day any falling off in the plant efficiency due to such auxiliary equipment not being operated properly is readily detected. A daily report giving a complete summary of station economy, readings of generation by units, and power distribution is sent to the general office.

One company besides making up a daily operating summary, which is a complete analysis of the plant operation, makes a daily graph giving all the more important information pertaining to the day's operation. This system of recording data has proved exceptionally valuable in checking back to find the cause of changed conditions. Great care is exercised in collecting data so that all reports will be as nearly accurate as possible.

Another company reports its plants by sending daily reports of operation to the general office supplemented by a weekly report. The daily reports give such information as generation, oil consumption, turbine and boiler hours, station power and load conditions. The weekly report adds to the daily report the plant efficiency, steam consumption of turbines, condition of condensers, feed water temperatures and boiler efficiencies.

Stimulating Interest in Work

No companies report the use of a bonus system. The straight monthly or daily wage system is used, the tendency being to put more and more of the men on the monthly basis, using the daily basis only for temporary positions. The bonus system is difficult to apply to power plant operation owing to the large number of variables that enter into operating results, particularly the great variation in load from time to time. The interest of the men in the work is kept up by obtaining competition between different plants or between shifts or groups of men in one plant.

Enthusiasm of employees of one company is stimulated by the monthly award of a progress cup which is awarded to the department showing the greatest progress. This company controls the efficiency by careful study of operating records and comparing methods.

One company places the shifts on a competitive basis by posting the results of the operation of each of the three daily shifts. The results are compared with predetermined operating efficiency calculated from the

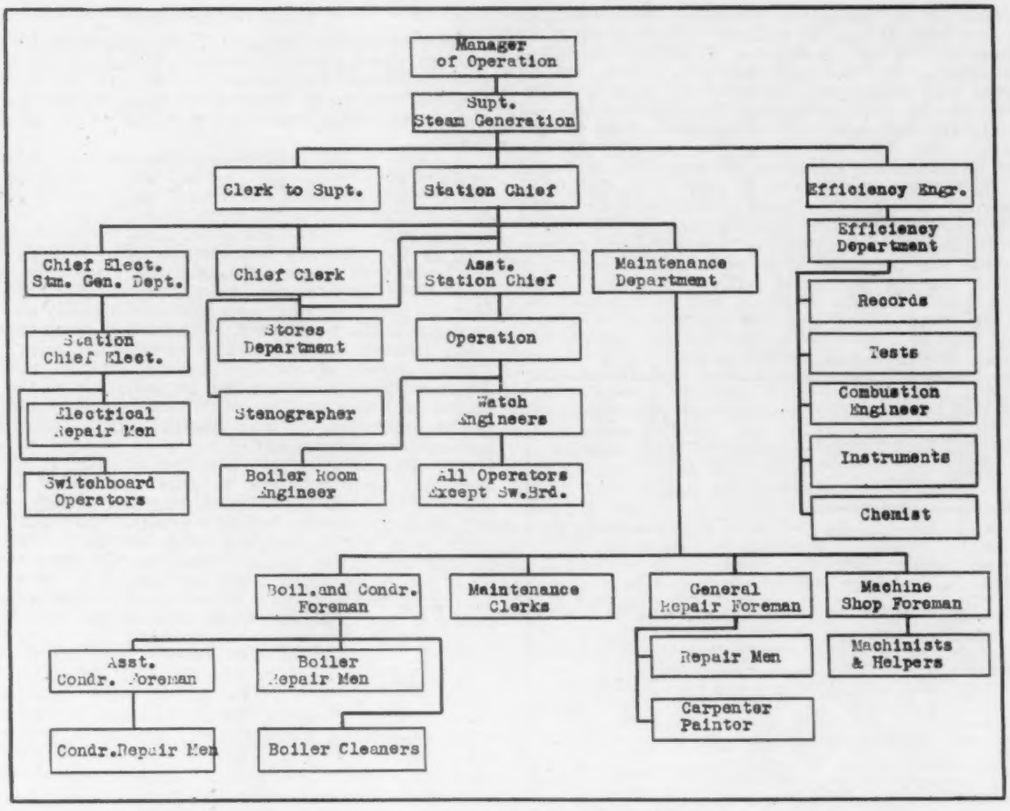


Fig. 1. A steam plant organization diagram showing relation to and ties with the general office.

heat-balance of the stations at maximum boiler efficiency for the different kinds of fuel used.

Another company stimulates interest in efficiency by establishing a standard amount of fuel which should be burned for any given load during the 24 hours. This standard is established as the average result obtained during the preceding year when operating under similar conditions. This standard is not a theoretical standard impossible to attain, but it is something that is known to have been reached before, and therefore should be reached again, and beaten if possible. By comparing the actual fuel burned with the standard, the efficiency obtained at various stations can be compared, and since each plant sets its own standard the results obtained depend upon the efforts of the plant operators regardless of whether one plant has more efficient units than another. These results are tabulated each month and a report sent out to the various stations. This method has been very effetcive in creating interest among the men and it is found that they are very much interested in seeing the comments made in the monthly report showing in what way improvements in efficiency in the different stations have been obtained.

Interest in the general cleanliness and appearance of the station is stimulated by a premium system extending over the entire system of the company. A system of rating schedules has been adopted and rating committees are formed who inspect all the stations of the company, rating each station according to the general appearance of the grounds, the buildings and structures, the employees' personal neatness, the condition of the records, the condition of painted surfaces, the polishing of bright surfaces, leakage of pipes, glands, valves; in fact, all the various details that go into what may be called good housekeeping of the stations. In this work the age or relative importance or capacity of the particular property are not considered factors in establishing the rating, emphasis being placed upon such conditions as are under the control of and dependent upon the interest, attention and effort of the attendants. Each division appoints a rating committee to inspect all the properties in that division. The stations receiving the highest ratings in each division then are inspected by a general rating committee from the general office. This general rating committee inspects as many of the properties in each division as may be necessary to determine fairly the awards. First, second and third prizes are awarded in each of three classes of properties; namely, electric substations, steam plants and hydro-electric plants. The station receiving the highest rating of all properties in all classes also receives special recognition.

Another means of stimulating interest in work is the "suggestion contest." This contest is open to all employees excepting officials of the company, heads of departments and division managers. Suggestions may have for their object improvement in efficiency, economy, service, safety conditions, or public relations. They may refer to design, construction, operaing or maintenance methods, records, accounting, tools, or labor saving devices. Suggestions are submitted to the company's research committee either under the suggestor's own name or under an assumed name. Three cash prizes are awarded during the year—a prize of $100 for the best suggestion, $50 for the second best and $25 for the third best suggestion. In addition the research committee may award other prizes for meritorious suggestions.

Employees' Welfare

One company reports that questionnaires on operation and construction of equipment are circulated among the employees which they are required to answer. A set of correct answers is later posted. Occasional talks on subjects of general interest are given and once in a while films are shown.

Sickness and disability, when not covered by the industrial accident commission, are handled as follows: For monthly men, full pay up to one and one-half days for each month of active service; maximum allowance computed on the preceding twelve months. Daily men receive nothing for the first day's absence; one-half time for the second to eighth day and after the eighth day under the same rules as the monthly men.

A mutual death benefit association is maintained among the employees wishing to belong. A payroll deduction of 60 cents per death is made and the association is now paying about $2,000 per death. Medi-

cal dues of 50 cents per month deducted from the payroll entitle the employees to full medical attention.

Employees reaching the age of 60 years, having 20 years continuous service are entitled to a monthly pension amounting to two per cent of the average monthly wage over the highest five years, multiplied by the number of years of service. Pension benefits for the higher salaried employees and officials are reduced on a sliding scale. A lunchroom and library are maintained and employees are urged to use them.

Another company has an association of employees organized for social and educational purposes. All employees are eligible to membership in the association the annual dues being $3.00 per year. All members of the association are entitled to a death benefit of $500. Members of the association may also join in a disability plan at the expense of $1 per month, deducted from the payroll, which entitles them to $20 a week sick benefit after the first week and continuing for 15 weeks. Then for the next fifteen weeks no benefits are paid. If the member is still disabled after these 31 weeks the benefits run again for another 15 weeks, when all benefits stop.

The educational courses offered by the association have been written by employees and are taught by employees. The subjects taught cover every scope of the company's activities. Employees who cannot come to a central point for instruction are given correspondence courses. On Feb. 1, 1928, five per cent of the company's employees were availing themselves of the opportunity to learn in 16 different courses of 84 groups. This is somewhat below the average number of students because some of the courses had not yet been started. The company itself offers a pension to any employee over 65 years of age who has been with the company for 15 consecutive years.

In general it may be said that all the companies have gone into employee welfare work quite thoroughly, this work embracing various phases of educational, social and athletic activities. As an example of the various activities one company reports a Masonic club with a membership of 325, a women's club, dramatic club, and after-hour club (the membership of this latter club is limited to 30 experienced public speakers, all employees, who meet twice each month at a 6 o'clock dinner, after which a flood of oratory begins), a compound-interest club (teaching savings and thrift to employees) and on Old Guard organization, present membership 345. This latter organization is made up of employees who have been in the employ of the corporation for more than 10 years.

The various clubs and social activities ordinarily are initiated and fostered by the employees themselves, and encouraged by the companies.

Boilers, Furnaces and Accessories*

The report of this subcommittee contains physical and operating data obtained from the various member companies who have installed new apparatus during the last few years. The general tendency seems to be to put in boilers of large size and increased pressure. While pressures of about 460 lb. and temperatures of 750 deg. F. are about the maximum that are being installed on the Pacific Coast there are studies now being made for an installation using 1,200 lb. pressure and 750 deg. F. total temperature.

While some stations have found the use of air-cooled furnace walls very satisfactory the majority of installations now going in are using water-cooled walls. Both have proved satisfactory in service and what troubles have appeared have been minor and easily remedied.

As may be noticed from the following statements superheater troubles have come up from time to time and the methods used in overcoming these may be of considerable value to those who find similar diffiiculties.

Air heaters so far have proved very satisfactory and there does not seem to be much difficulty arising from their use.

Statement of San Diego Consolidated Gas & Electric Company

Our experience with water-cooled furnaces, air preheaters and radiant superheaters began with the installation of a new boiler No. 28, which was a B & W cross drum type of 10,942 sq.ft. heating surface and similar to five other boilers in service for about five years.

No. 28 was placed in service Nov. 15, 1926, and had been in active operation 7,478 hours to Dec. 24, 1927. The water-cooled walls are in good condition to date. Although very little scale was present the tubes of the water walls were bored March 26, 1927. At this time some slag was removed from the water-cooled floor and a light coating of a special cement was applied where some of the brick facing of the water wall blocks had adhered to the slag.

The air preheater in boiler No. 28 has given good service, but some trouble developed in the preheater of boiler No. 23 which was placed in service June 18, 1927,

Fig. 1. View of front and side wall taken Nov. 14, 1927.

after a remodeling which included installation of the same equipment as on No. 28. The air preheaters are divided in two sections for forced and induced draft and both fans are mounted on one shaft and driven by a 150-hp. motor. The three bolts holding the inner bearing of the fan shaft broke Aug. 30 and it was necessary to install new fans and shaft. The manufacturers have installed a new type of bearing support with more and larger holding bolts and we do not expect any more trouble of that kind.

As the space for preheaters was rather small it was necessary to run them at high speed to get the capacity required and as a result they were quite noisy. Some special ducts are now being installed for the air to the preheaters and the noise is greatly reduced. Two-stage forced draft fans of a new type were installed for the last two preheaters. These are less noisy than the first three.

The radient type superheaters have been in service in No. 28 since Nov. 15, 1926; in No. 23 since June 18,

Fig. 2. Rear wall of boiler No. 28 after one year's service.

1927, and in No. 21 since Aug. 31, 1927. Each superheater contains 52 forged steel elements 5 ft. 6 in. long, located at the rear of the furnace under the mud drum. Steam is taken from the connection type superheaters above the boiler tubes and then makes two passes through the radiant type superheaters. Steam temperatures from the radiant type superheaters are about 700 deg. F.

* Report of subcommittee of prime movers committee.

TABLE I—Summary of results—Tests on Boiler, Superheater and Air Preheater, Los Angeles Gas and Electric Corporation, Seal Beach Station.

EQUIPMENT DATA:

BOILER—2,545 h.p., 385-lb. pressure, 14 combination oil-and-gas burners.
SUPERHEATER—Triple-loop, single-pass type, present area 3,010 sq. ft., completed area 3,331 sq. ft.
AIR PREHEATER—Tubular type, 1,984 2½-in. tubes 18 ft. long, 23,025 sq. ft. heating surface.
FURNACE—Special air-cooled cast-iron, cooling boxes.

	Item	Test No.	1	2	3	4	5	6	7	8	9	10
1.	Date, 1925		June 19	June 22	June 24	June 25	July 7	July 16	July 23	July 25	July 25	July 28
2.	Duration, hours		5	5	5	5	4	6	6	4	4	3
3.	Boiler rating, per cent		149	200	250	124	292	195	244	112	151	265
4.	Boiler, number average conditions		1	1	1	1	1	1	1	1	1	1
5.	Steam pressure-boiler drum, lb. per sq. in.		375	372	375	372	376	372	374	375	375	375
6.	Number of burners in operation		10	14	14	9	14	14	14	9	11	14
7.	Oil pressure at burners, lb. per sq. in.		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8.	Gas pressure at burners, lb. per sq. in.		4.50	4.00	5.50	4.00	7.50	.....	.....	.....	.....	.....
9.	Air pressure at burners, inches water		0.60	0.78	1.40	0.80	2.00	2.20	3.20	1.50	1.80	4.00
10.	Draft—furnace, in. of water		0.18	0.10	0.07	0.05	0.03	0.10	0.10	0.15	0.10	0.10
11.	Draft—under damper, in. of water		0.25	0.50	0.88	0.10	1.18	0.52	0.82	0.10	0.26	1.30
12.	Draft—under heater, in. of water		1.00	0.95	0.95	1.00	1.16	1.05	1.00	0.95	1.10	1.30
13.	Draft—above heater, in. of water		1.00	1.00	1.10	1.00	1.06	1.05	1.05	0.88	1.00	1.20
14.	Draft loss through boiler, in. of water		0.07	0.40	0.81	0.05	1.15	0.42	0.72	0.05	0.16	1.20
15.	Draft loss through heater, in. of water		0.10	0.15	0.25	0.10	0.00	0.10	0.15	0.03	0.00	0.00
16.	Temperature—fuel oil, deg. F		.....	.....	.....	.....	.....	170	180	175	180	200
17.	Temperature—feed water, deg. F.		328	338	348	398	345	350	350	340	350	350
18.	Temperature—air entering heater, deg. F.		77	72	84	84	75	86	85	80	76	80
19.	Temperature—air leaving heater, deg. F.		310	308	318	292	252	315	315	276	290	230
20.	Temperature rise through heater, deg. F.		233	236	234	208	177	229	230	196	214	150
21.	Temperature—air entering side wall boxes, deg. F.		310	308	318	292	252	315	315	276	290	230
22.	Temperature—air leaving side wall boxes, deg. F.		330	338	348	325	290	358	358	330	340	270
23.	Temperature rise through side wall boxes, deg. F.		20	30	30	33	38	43	43	54	50	40
24.	Temperature—air entering rear wall boxes, deg. F.		310	308	318	292	252	315	315	276	290	230
25.	Temperature—air leaving rear wall boxes, deg. F.		345	350	354	340	290	360	362	345	342	272
26.	Temperature rise through rear wall boxes, deg. F.		35	42	36	48	38	45	47	69	52	42
27.	Temperature—air entering under furnace floor, deg. F.		337	344	350	332	290	359	360	337	341	271
28.	Temperature—air leaving under furnace floor, deg. F.		355	365	370	355	312	380	382	375	380	305
29.	Temperature rise passing under furnace floor, deg. F.		18	21	20	23	22	21	22	38	39	34
30.	Total temperature rise—heater to burner, deg. F.		278	293	286	271	237	294	297	295	304	225
31.	Temperature—gas leaving boiler, deg. F.		472	498	520	459	540	545	567	470	501	615
32.	Temperature—gas leaving heater, deg. F.		235	275	297	230	.....	305	326	230	265	.....
33.	Temperature drop through heater, deg. F.		237	223	223	229	.....	240	241	240	236	.....
34.	Temperature—furnace, 5 ft. from burner wall, deg. F.		2,330	2,362	2,420	2,178	2,405	2,835	2,940	2,472	2,670	3,010
35.	Temperature—furnace, 10 ft. from burner wall, deg. F.		2,330	2,362	2,420	2,178	2,405	2,584	2,685	2,363	2,543	2,830
36.	Temperature—steam, superheater outlet, deg. F.		600	630	640	593	664	656	675	626	636	658
37.	Degrees superheat, F.		157	187	197	150	221	213	232	183	193	215
38.	Gas (CO_2), top of 3rd pass, per cent		10.70	10.70	10.80	10.50	10.90	14.60	14.60	14.40	14.30	14.50
39.	Gas (O_2), top of 3rd pass, per cent		2.10	2.30	2.00	2.10	1.90	1.30	1.30	1.40	1.40	1.20
40.	Gas (CO), top of 3rd pass, per cent		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41.	Gas (N_2), top of 3rd pass, per cent		87.20	87.00	87.20	87.40	87.20	84.10	84.10	84.20	84.30	84.30
42.	Gas (CO_2), leaving heater, per cent total quan.		10.20	10.10	10.20	9.60	10.40	14.20	14.30	14.00	14.00	14.10
43.	Actual evaporation (Venturi Meter), lb.		126,000	168,000	210,000	104,000	242,000	164,000	202,000	94,000	129,000	224,000
44.	Equivalent evaporation, lb		130,788	175,728	219,030	108,992	256,278	171,380	214,220	98,136	132,870	234,080
45.	Factor of evaporation, hourly quantities		1.038	1.046	1.043	1.048	1.059	1.045	1.060	1.044	1.030	1.045
46.	Fuel consumed per hr. (calculated), lb.		7,184	9,620	12,015	5,750	.....	9,740	12,230	5,488	7,503	.....
47.	Gas passing through heater per hr., lb.		140,734	188,552	233,571	114,482	.....	156,521	196,530	89,288	122,674	.....
48.	Air passing through heater per hr., lb		133,550	178,932	221,556	108,732	.....	146,781	184,300	83,800	115,171	.....
	Economy											
49.	Dry gas per lb. carbon burned, lb		23.20	23.21	23.00	23.62	22.80	17.34	17.34	17.57	17.66	17.45
50.	Dry gas per lb. fuel burned, lb		17.47	17.48	17.32	17.79	17.17	15.08	15.08	15.28	15.36	15.18
51.	Air per lb. fuel passing through heater, lb		18.59	18.60	18.44	18.91	18.29	15.07	15.07	15.35	15.35	15.17
52.	Total gas per lb. fuel passing through heater, lb.		19.59	19.60	19.44	19.91	19.29	16.07	16.07	16.27	16.35	16.17
53.	Moisture per lb. fuel from hydrogen, lb.		2.12	2.12	2.12	2.12	2.12	0.99	0.99	0.99	0.99	0.99
54.	Fuel Analysis:											

Natural Gas				Fuel Oil	
By Volume		By Weight		By Weight	
CO_2	0.008	Carbon	75.30	.....	
C_nH_{2n}	0.003	Hydrogen	23.54	Carbon	87.01
O_2	0.001	.....		Hydrogen	11.00
C_2H_6	0.248	.....		Nitrogen	0.65
CH_4	0.737	.....		Sulphur	1.14
N_2	0.003	.....		Water	0.20

55.	Calorific value of 1 lb. fuel B. t. u.			21,300						19,280	
	Heat Balance:										
56.	Heat absorbed, per cent	84.29	83.18	83.01	84.57	.....	88.54	88.08	89.95	89.08	.....
57.	Heat loss due to burning hydrogen, per cent	11.11	11.35	11.33	11.01	.....	5.85	5.90	5.70	5.81	.....
58.	Heat loss due to dry flue gases, per cent	3.10	3.97	4.16	2.92	.....	4.11	4.52	2.85	3.61	.....
59.	Heat unaccounted for, per cent (assumed)	1.50	1.50	1.50	1.50	.....	1.50	1.50	1.50	1.50	.....
60.	Heat absorbed by boiler only, per cent	78.49	77.70	77.00	78.87	76.92	84.00	82.94	84.79	84.01	82.71
61.	Heat entering heater with dry gases per lb. fuel, B. t. u.	1,655	1,787	1,814	1,601	.....	1,662	1,745	1,431	1,564	.....
62.	Heat entering heater with wet gases per lb. fuel, B. t. u.	2,607	2,625	2,642	2,580	.....	1,241	1,255	1,214	1,232	.....
63.	Total heat entering heater per lb. fuel, B. t. u.	4,262	4,412	4,456	4,181	.....	2,903	3,000	2,645	2,796	.....
64.	Heat leaving heater with dry gases per lb. fuel, B. t. u.	662	847	886	623	.....	792	872	550	696	.....
65.	Heat leaving heater with wet gases per lb. fuel, B. t. u.	2,368	2,419	2,415	2,346	.....	1,130	1,140	1,100	1,121	.....
66.	Total heat leaving heater per lb. fuel, B. t. u.	3,030	3,266	3,301	2,969	.....	1,922	2,012	1,650	1,817	.....
67.	Heat evolved by gases, B. t. u.	1,232	1,146	1,155	1,212	.....	981	988	995	979	.....
68.	Heat absorbed by air, B. t. u.	1,039	1,053	1,036	945	.....	828	833	718	789	.....
69.	Heat unaccounted for, B. t. u.	193	93	119	267	.....	153	155	277	190	.....
70.	Per cent	4.52	2.10	2.67	6.39	.....	5.27	5.17	10.47	6.79	.....
71.	W/A Gas, A = 56.3 sq. ft	2,500	3,349	4,149	2,034	.....	2,780	3,491	1,586	2,179	.....
72.	W/A Air, A = 64 sq. ft.	2,087	2,796	3,462	1,699	.....	2,293	2,880	1,309	1,799	.....
73.	Mean temperature diff., deg. F.	160	197	207	156	.....	225	246	172	200	.....
74.	Heat transfer rate	2.03	2.23	2.61	1.51	.....	1.56	1.79	1.00	1.29	.....

TABLE II—Boiler No. 1, temperatures of air ducts and furnaces.

June 24, 1925, 250 per cent rating, by-pass damper closed, 14 burners on, boiler flow 210,000 pounds per hour, gas-fired.

Item	Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
75	12:00	446	462	505	480	500	485	483	490	485	490	550	535	503	545	520	505	355	355
76	12:30	450	465	510	480	505	490	485	490	485	495	555	535	505	545	520	510	355	360
77	1:00	450	470	510	485	505	490	485	495	488	494	558	540	510	548	523	510	360	360
78	1:30	455	470	515	488	510	495	485	494	490	496	558	542	514	550	528	517	363	365
79	2:00	455	473	515	490	512	494	485	495	492	496	559	542	514	554	527	515	360	365
80	2:30	455	472	514	492	514	496	486	498	493	499	562	545	516	555	528	516	358	363
81	3:00	455	472	514	496	516	499	487	500	496	500	561	548	516	557	531	518	358	364
82	3:30	458	476	518	498	516	503	488	503	497	502	564	550	518	558	532	520	361	368
83	4:00	458	475	516	500	516	503	490	502	498	502	562	548	518	558	532	520	360	366
84	4:30	457	475	516	500	516	502	490	502	500	502	562	550	518	558	532	520	362	365

Steam temperature.

Item	Time	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
85	12:00	345	375	368	560	655	590	88	322	322	345	355	370	530	532	...	298	640	640
86	12:30	345	380	370	565	655	590	88	322	322	348	356	370	527	531	...	298	643	639
87	1:00	350	380	370	567	658	592	90	322	322	348	356	370	528	531	...	297	643	637
88	1:30	353	380	375	570	660	592	90	322	322	350	358	370	528	531	...	300	642	636
89	2:00	352	382	375	571	662	597	85	318	318	348	356	368	525	528	...	297	639	634
90	2:30	350	382	375	571	663	597	82	318	318	349	355	370	526	530	...	297	639	635
91	3:00	351	382	375	573	667	600	80	315	315	347	354	367	524	530	...	395	639	637
92	3:30	352	385	378	576	666	602	78	315	318	350	356	370	527	530	...	296	642	636
93	4:00	352	386	376	578	665	602	78	315	315	349	354	368	525	532	...	296	640	638
94	4:30	351	385	375	580	665	604	78	315	315	348	354	367	526	530	520	295	640	638

We have had no failures to date, but some of the elements in the second pass in boiler No. 28 have been pretty well cooked and some steel has been burned away from the surfaces exposed to the fire.

In July, 1927, the manufacturer of the radiant type superheater had six iron bars of about ¾-in. diameter welded across the width of the upper ends of the elements about 2 in. apart as a protection from the fire.

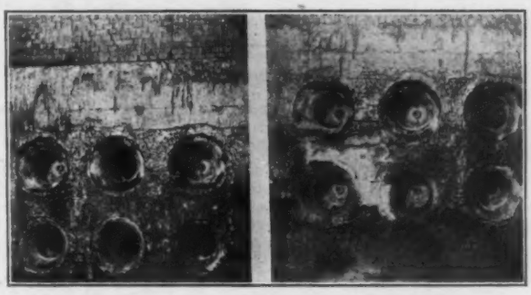


Fig. 3. Front wall No. 1 boiler Feb. 8, 1927, after 3,600 hours service, 2,628 hours on gas and 972 hours on fuel oil. Twelve drums of repair material were used in repairing this wall.

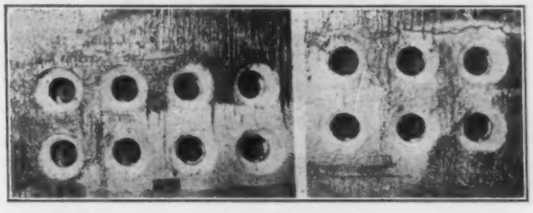


Fig. 4. Front wall No. 1 boiler May 31, 1927. This shows the repairs mentioned in Fig. 3 after 1,323 hours of operation, 1,145 on gas and 178 on oil.

Bars have also been welded on the elements of all other superheaters which have been installed.

We have two new boilers and three of the older ones equipped with the apparatus described and the two remaining older ones will probably bo so equipped during the coming year.

Statement of Los Angeles Gas and Electric Corporation Seal Beach Station

Boilers, Furnaces and Accessories—The first unit of the Seal Beach station was placed in operation on June 2, 1925. This unit is rated as 35,000 kw. The steam is supplied with three B & W cross drum boilers. Each boiler contains 25,450 sq.ft. of heating surface. The tubes number 860 and are arranged 43 tubes wide and 20 tubes high. All tubes are No. 7 B.W.G. except the two bottom rows which are No. 6 B.W.G. Working pressure is 385 lb. per sq.in. gage.

To Jan. 1, 1928, the boilers operated a total of approximately 34,171 hours. No trouble has been caused due to either design or construction of the boilers proper. Very little cleaning has been necessary due to the excellent condition of the feed water. The attached photostat of boiler drawing shows clearly the boiler furnace and superheater arrangement.

The furnaces of the boilers are designed for the burning of gas or oil and are of the air cooled wall type. The air for combustion is drawn through the preheater and forced through the cast iron ducts (shown in print A) downward to the double floor and under the floor to the boiler front. The temperature rise through this wall and floor construction is shown in the accompanying test sheets. The fire brick used in the original setting was Walsh XX. Special shapes were used for the burner arches and around the ducts.

During March, 1926, nine months after the plant started operating, it was found necessary to renew the two I-beams above the wind box which support the upper front wall of the furnace. When natural gas was used as fuel it was found that a small part of it would not enter the furnace through the Ventura shaped opening, but would follow under the brick work and burn in between these beams. Added to this it was found that the gas chamber which surrounded the annular slot of the gas burner would crack due to temperature strains. This also permitted the gas to leak from the burners and follow any crevice under or in the brick work with the result that the entire front had the appearance of burning. This trouble was overcome by sealing the beams off from the furnace and placing vents so that a positive circulation of air from the boiler room passes through them. At either end of the beam a stack is connected to give this circulation. A partition is in the center of the beams with a vent adjacent to the partition. In this manner the circulation is positive from the center of the beams to the ends and up the stack as provided. The furnace pressure is now always lower than in between the beams. The burner design was changed so that no more trouble is encountered due to the gas chamber cracking. The front walls are now built up of plastic material as shown in the photographs. Instead of using the special shaped brick around the burners, a form is used and plastic material is shaped to give the Ventura opening.

Some change is being made in the floor construction for the new boilers which are being installed. It was found that the concrete slab on which the boiler floor is supported is too thick to carry away properly the heat in the air circulating under the floor. As a result, the boiler floor under the new units will be supported on steel plates, which will give a better chance to radiate

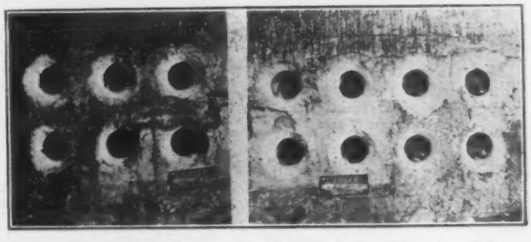


Fig. 5. The same as Fig. 4 except showing effect of 2,934 hours of additional operation, 2,905 on gas and 29 on fuel oil.

TABLE III—Boiler No. 1, temperatures of air ducts and furnaces.

June 24, 1925, 250 per cent rating, by-pass damper closed, 14 burners on, boiler flow 210,000 pounds per hour, gas-fired.

Item	Time	Feed Water Temp.	Furnace Temp.	Air Duct Pressure	Furnace Draft	Under Damper	Under Heater	Above Heater	Steam Pressure	Gas Pressure	CO_2
95	12:00	346	2414	1.40	0.09	0.90		1.10	370	5.5	
96	12:30	348	2419	1.38	0.10	0.90		1.10	372	5.5	10.0
97	1:00	346	2414	1.38	0.10	0.90		1.10	375	5.6	
98	1:30	348	2419	1.38	0.10	0.90	0.95	1.10	380	5.5	
99	2:00	350	2426	1.40	0.08	0.88		1.10	375	5.5	10.2
100	2:30	350	2419	1.40	0.08	0.88		1.10	376	5.5	
101	3:00	348	2426	1.40	0.07	0.88	0.95	1.10	375	5.5	
102	3:30	348	2419	1.40	0.07	0.88		1.10	376	5.5	10.0
103	4:00	350	2426	1.40	0.07	0.88		1.10	375	5.5	
104	4:30	348	2419	1.40	0.07	0.88	0.95	1.10	376	5.5	

TABLE IV—Boiler No. 1, temperatures of air ducts and furnaces.

June 25, 1925, 125 per cent rating, by-pass damper closed, 9 burners on, boiler flow 104,000 pounds per hour, gas-fired.

Item	Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
105	4:30	365	340	360	350	370	350	355	365	370	380	465	420	395	415	405	395	280	290
106	5:00	370	355	375	370	385	370	375	380	390	395	475	435	410	435	420	410	282	295
107	5:30	385	375	400	395	410	395	400	405	410	415	490	455	430	460	445	435	290	300
108	6:00	400	400	420	415	430	415	425	430	430	440	510	485	455	485	465	455	300	310
109	6:30	410	410	440	435	450	435	440	445	445	455	525	495	470	495	485	465	305	320
110	7:00	415	420	450	445	460	450	455	455	460	465	535	505	480	515	495	485	315	325
111	7:30	425	430	460	455	470	460	460	460	465	475	540	525	490	525	505	495	320	335
112	8:00	435	435	465	460	480	470	470	470	470	480	550	530	500	530	510	505	324	340
113	8:30	435	440	470	465	485	475	475	475	475	485	550	530	503	535	515	510	326	342
114	9:00	440	440	470	465	485	475	475	475	475	485	550	530	505	535	515	512	326	342

Steam temperature.

Item	Time	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
115	4:30	285	315	315	570	665	605	85	292	292	315	315	335	470	470	...	228	595	595
116	5:00	290	325	320	570	665	600	82	292	292	315	320	340	470	470	...	228	595	595
117	5:30	295	330	325	570	665	600	85	290	290	312	322	340	465	470	...	228	595	595
118	6:00	305	340	335	565	660	595	82	290	290	315	332	345	465	465	...	228	595	593
119	6:30	310	350	345	560	655	595	83	292	292	315	330	345	465	466	...	230	594	593
120	7:00	315	360	350	560	655	595	85	292	292	320	335	350	465	463	...	232	595	595
121	7:30	325	365	350	555	650	590	85	292	292	320	335	355	464	465	...	232	590	592
122	8:00	334	370	355	555	650	590	85	293	293	325	340	355	464	463	...	232	590	590
123	8:30	337	375	368	555	650	590	85	292	292	325	340	355	464	465	459	232	592	590
124	9:00	337	375	360	555	650	590	84	292	292	325	340	355	464	464	...	232	590	588

the heat through the medium of the air passing directly under.

The side and rear walls have been the source of but little trouble. The maximum spalling to date is approximately 1 in. When burning gas, no trouble is encountered with the brick work. This is undoubtedly due to the fact that there are no chemical constituents which will flux with the brick to lower its melting

Fig. 6. South wall No. 1 boiler Nov. 7, 1927, after 10,469 hours of operation, 8,882 on gas and 1,587 on oil. The back wall was in similar condition.

point. However, when burning oil, some ingredient forms a flux which causes the brick surface to flow.

It has been necessary in one instance to repair the side wall to one of the furnaces. There are several rows of brick which are above the tie that protect the top L-shaped cast iron duct. There is an expansion joint between the top of these rows of brick and the wall above. The tile in the wall above evidently spalled, filling this joint with clay, causing the wall to bulge. This exposed the ducts and structural work in the setting at this point which had to be renewed. Other than this no trouble has been caused by the side and rear walls. The total furnace volume is approximately 9,700 sq.ft.

The manifold to the air duct was changed in order to facilitate repairs to the expansion joints. The manifold was moved away from the boiler to give sufficient room to stagger these joints. One joint is on the manifold end and the next one is on the duct end of the spacers installed.

The superheaters are located as shown in copy of print marked A. They are the inter-deck three-loop type. Each superheater contains 3,331 sq.ft. of surface. The average superheat obtained is approximately 250 deg. F. It is necessary to inspect periodically the distributing nozzles on the inlet end of the tubes. These nozzles are installed to prevent the steam from laning, and it is very necessary to have them properly installed.

The air preheaters are installed at the flue gas outlet of each boiler. The preheaters are tubular, three-pass, and each contains 23,025 sq.ft. of heating surface. There are 1,984 No. 11 gage tubes, 2 in. outside diameter; each tube is 18 ft. long. The tubes are so arranged that the flue gases pass upward through the tubes and the air passes downward outside the tubes making three complete passes over the tubes.

The soot blower equipment is as follows:

Eleven elements on each side or a total of 22 elements to each boiler. Nine elements on each side are the rotating valve-in-head type, chain operated. All valve seats, discs and other working parts coming in contact with superheated steam are of natural Monel metal. The heads are supported by the steel boiler casing. The elements are supported upon every alternate tube to reduce warping to a minimum. The units or elements are known as calorized metal.

However, there is a tendency for these elements to distort or warp making it difficult to rotate them. Also when warped, the path of the steam is deflected from the course it was intended for it to take in order to clean the tubes. This greatly reduces their effectiveness. It is very necessary that the superheater tubes be blown regularly. The element for soot blowing in the preheater tubes is supported on a carriage which travels back and forth under the tubes. The carriage is geared to a hand wheel on which there is a marking for each row of tubes. The carriage is stopped with the element directly under the row of tubes to be blown and the steam is turned on. Piping with flexible joints

TABLE V—Boiler No. 1, temperatures of air ducts and furnaces.

June 25, 1925, 125 per cent rating, by-pass damper closed, 9 burners on, boiler flow 104,000 pounds per hour, gas-fired.

Item	Time	Feed Water Temp.	Furnace Temp.	Air Duct Pressure	Furnace Draft	Under Damper	Under Heater	Above Heater	Steam Pressure	Gas Pressure	CO_2
125	4:30	312	2194	0.80	0.02	0.10		1.00	375	4.0	
126	5:00	312	2194	0.80	0.02	0.10		1.00	370	4.0	
127	5:30	315	2178	0.80	0.02	0.10	1.00	1.00	375	4.0	9.4
128	6:00	318	2178	0.80	0.02	0.10		1.00	370	4.0	
129	6:30	315	2162	0.80	0.02	0.10		1.00	372	4.0	
130	7:00	320	2170	0.80	0.02	0.10	1.00	1.00	365	4.0	9.5
131	7:30	320	2178	0.80	0.02	0.10		1.00	375	4.0	
132	8:00	322	2170	0.80	0.02	0.10		1.00	375	4.0	
133	8:30	320	2178	0.80	0.02	0.10	1.00	1.00	372	4.0	9.6
134	9:00	320	2178	0.80	0.02	0.10		1.00	370	4.0	

TABLE VI—Boiler No. 1, temperatures of air ducts and furnaces.

July 7, 1925, 290 per cent rating, by-pass damper open, 14 burners on, boiler flow 242,000 pounds per hour, gas-fired.

Item	Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
135	1:00	407	402	437	427	435	426	420	437	435	448	518	492	464	493	469	456	311	325
136	1:30	387	392	428	420	439	420	428	425	425	438	503	485	450	480	457	443	299	306
137	2:00	380	391	428	420	436	426	435	428	428	441	498	485	446	482	451	438	293	303
138	2:30	380	394	432	429	440	433	432	431	432	445	499	490	451	487	455	440	291	300
139	3:00	380	398	440	434	442	438	434	434	438	450	500	495	454	492	457	445	293	299
140	3:30	384	404	444	434	450	442	439	436	438	454	505	500	456	496	458	447	295	301
141	4:00	382	399	442	434	446	440	436	436	438	452	503	498	456	495	458	446	295	300
142	4:30	382	398	443	434	445	440	435	438	438	452	503	500	458	495	458	446	295	301

Steam temperature.

Item	Time	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
143	1:00	315	347	335	582	678	612	76	255	255	292	296	320	548	550	...	...	664	662
144	1:30	299	332	318	582	677	612	74	252	252	287	288	312	551	549	...	...	670	666
145	2:00	294	325	311	582	681	615	74	251	251	287	287	310	548	548	540	...	666	666
146	2:30	292	320	307	580	679	615	75	250	250	287	287	308	546	548	...	...	664	662
147	3:00	292	322	306	580	678	616	77	252	252	290	290	311	550	548	...	...	666	664
148	3:30	294	325	310	580	679	617	77	252	252	292	290	312	550	549	540	...	665	662
149	4:00	294	325	309	580	678	617	76	252	252	290	290	312	548	548	...	...	664	664
150	4:30	295	324	310	580	676	617	76	252	252	290	290	312	550	548	...	...	666	666

or couplings carries the steam to the element on the carriage.

A damper is provided between the two banks of tubes of each preheater in order to reduce the draft loss in the event higher ratings are required from the boilers. The maximum rating on the boilers with the preheaters in use is about 265 per cent. We can get approximately 300 per cent when by-passing the preheaters.

Statement of Southern California Edison Company

Soot Blowers—Two well known makes of soot blowers are in use in our No. 2 plant at Long Beach. In mechanical satisfaction and effective cleaning there is little in common, the one giving as nearly satisfactory service with a minimum of trouble as could be reasonably expected while the other is of opposite tendency, giving more trouble than should be expected and necessitating the use of reduced pressure on the heads with resultant poorer cleaning effect. Arrangement of the two makes in the boiler settings is practically identical, excepting that in the boilers of No. 7 and 8 units the soot blowers were installed after the boilers had been in service, burning oil and gas, for approximately three years, and differ from the arrangement on boilers of No. 9 unit only as was necessitated by the difference in the settings and their condition.

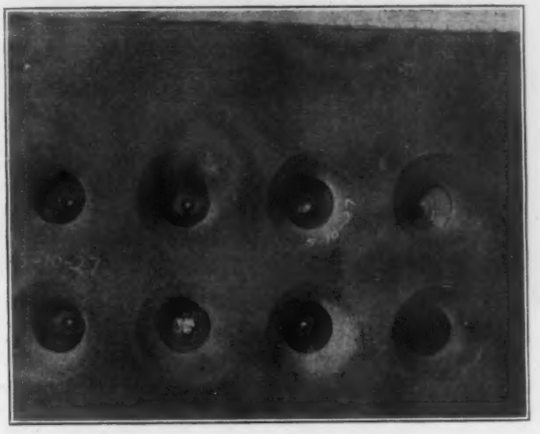


Fig. 7. Renewed front wall installed in No. 3 boiler May 10, 1927.

On superheaters with cast iron fin tubes the installation of soot blowers in front of the tubes did not prove entirely satisfactory and the idea of installing them inside the tube loops was resorted to with added satisfaction.

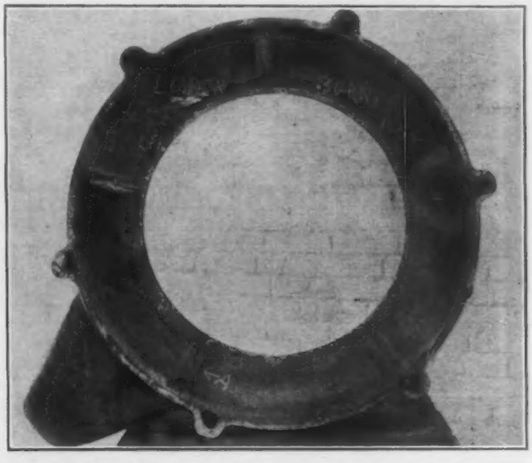


Fig. 8. Cracked burner casting which allowed gas to leak through crevices in settings, causing damage to boiler structural steel.

Orifices were installed originally in the piping of No. 9 unit to reduce the steam pressure from that of the boiler to approximately 250 lb. gage. This seemed satisfactory for the boiler proper, economizer, and air preheater, but was not sufficiently strong for cleaning superheater tubes. The orifice was then removed to a place in the piping that would allow full boiler pressure on the superheater soot blowers, but would protect all others. This probably gives the maximum of satifaction in soot blowing obtainable with our set-up.

TABLE VII—Boiler No. 1, temperatures of air ducts and furnaces.

July 7, 1925, 290 per cent rating, by-pass damper open, 14 burners on, boiler flow 242,000 pounds per hour, gas-fired.

Item	Time	Feed Water Temp.	Furnace Temp.	Air Duct Pressure	Furnace Draft	Under Damper	Under Heater	Above Heater	Steam Pressure	Gas Pressure	CO_2
151	1:00	342	2380	1.86	0.07	1.20	1.18	1.14	370	7.0	
152	1:30	344	2383	1.86	0.07	1.21	1.19	1.14	375	7.5	
153	2:00	346	2400	1.86	0.07	1.21	1.19	1.14	375	7.5	
154	2:30	346	2383	1.92	0.05	1.19	1.17	1.08	373	7.5	
155	3:00	346	2420	1.98	0.03	1.19	1.17	1.08	375	7.5	
156	3:30	346	2428	2.00	0.03	1.18	1.16	1.06	370	7.5	
157	4:00	345	2420	2.00	0.03	1.18	1.16	1.06	375	7.5	
158	4:30	345	2420	2.00	0.03	1.18	1.16	1.06	378	7.5	

On boilers No. 33 to 36, inclusive, there are:

5 elements—right—containing 25 nozzles on boiler
5 elements—left—containing 25 nozzles on boiler
1 element—right—containing 56 nozzles on superheater (inside loop)
1 element—left—containing 56 nozzles on superheater (inside loop).
8 elements—vertical on economizer
20 elements—total.

On boilers No. 37 to 40, inclusive, there are:

5 elements—right—containing 25 nozzles each on boiler
5 elements—left—containing 25 nozzles each on boiler
8 elements—left on economizer
18 elements—total.
(There are no soot blowers on superheaters of boilers No. 37 to 40.)

On boilers No. 41 to 47, inclusive, there are:

5 elements—right—containing 25 nozzles on boiler
5 elements—left—containing 25 nozzles on boiler
2* elements—right—containing 30 nozzles on superheater
2* elements—left—containing 30 nozzles on superheater
6 elements—right—containing 32 nozzles on economizer
6 elements—left—containing 32 nozzles on economizer
12 containing 29 nozzles on air preheater
38 Total.
*No. 44 boiler has no soot blowers on the superheaters.

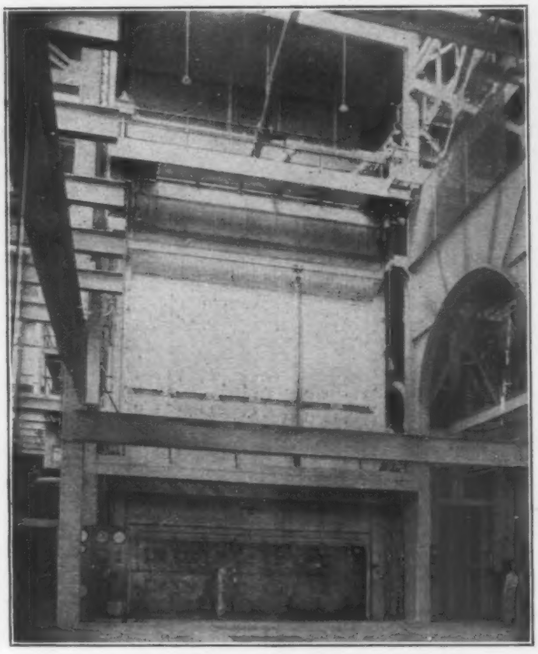


Fig. 9. Front of one of the 2,545-hp. cross-drum boilers.

On this group of boilers steam is supplied to right hand soot blower elements from the second pass of the superheater at a temperature of approximately 600 deg., and to the left hand elements steam comes from the supehheater outlet at 720 to 730 deg. and protection from high pressure on all but superheater blowers is provided by an orifice in the pipe line.

On boilers No. 33 to 40, inclusive, the steam is supplied to soot blowers from the superheater outlet. Pressure reduction was first made through use of an orifice in the line, but after suffering two soot blower head failures, apparently due to too high pressure, it was decided to install reducing valves on all supply lines, to hold pressure to a maximum of 175 lb. With one soot blower element in operation the pressure at the head is 100 lb. and at the reducing value is 155 lb.

Superheaters—Three different makes of superheaters are in use in our No. 2 plant at Long Beach. There are two different arrangements of one make giving about equally satisfactory service when in the same condition of cleanliness, etc.

Boilers No. 33 to 36, inclusive, are equipped with bare tube double element superheaters of convection type placed just in front of the second bank of tubes. These superheaters are 114 tubes wide and tubes are 1¾ in. inside diameter and 2⅛ in. outside diameter. Superheater heating surface is 3,574 sq.ft. per boiler, arranged for three-pass steam.

Boilers No. 37 to 40, inclusive, are equipped with superheaters with tubes covered with cast iron fins to give an extended surface. They are of the convection type, placed just behind the first bank of tubes, are 80 tubes wide and of double elements. Tubes are 2 in. outside diameter. Heating surface in superheater is 5,780 sq.ft., counting the extended surface of the cast iron fins.

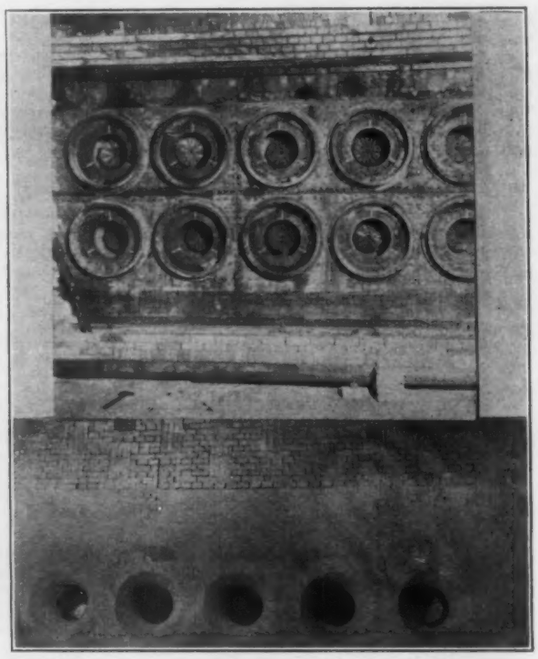


Fig. 10. (Above) Boiler front ready to install new wall. Segmental gas burners shown in place. (Below) No. 5 boiler May 18, 1927, showing the front wall above the burners after 8,224 hours of operation, 6,570 on gas, 1,654 on oil.

Single-pass Steam—Boilers No. 41 to 47, except No. 44, are equipped with superheaters with tubes covered with cast iron fins. They are 80 tubes wide, with triple elements. Tube sizes are the same as on boilers No. 37 to 40. These are placed just in front of the second bank of tubes and held in position by clamps attached to the second bank. Heating surface is 8,320 sq.ft. These superheaters are arranged for two-pass steam. Characteristics of these superheaters, except No. 44, are approximately the same as for any convection type

superheaters, varying more or less directly with the load on the boiler.

No. 44 boiler is equipped with a superheater very unlike the others. The headers are outside the boiler setting, across the top. The boiler is 77 tubes wide made up of 38 four-loop elements and 39 three-loop elements spaced in a single row. Connection between tubes and headers is by a ground ball joint held in place by a special steel stud and yoke for each two tubes.

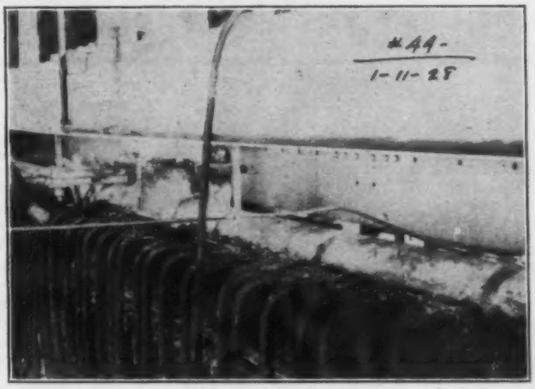


Fig. 11. A superheater on No. 44 boiler with housing removed, repairs being made to tubes after supports had been burned away.

Tubes extend downward through the roof of the boiler setting and the bank of short tubes between the front and center drums so that the loop elements occupy the space between the first and second banks of boiler tubes. Superheater tubes in this space are supported by spacer irons resting on the front bank of boiler tubes. Many of the superheater tubes are in direct line with the spaces between the boiler tubes of the front bank; thus considerable heat is obsorbed by radiation from the furnace, giving it an operating characteristic radically different from the other types in use here.

Fig. 12. (Above) Position of superheater in front of No. 2 bank showing accumulation between cast-iron fins.

Operation and Maintenance—Superheaters of boilers No. 33 to 36, inclusive, were originally installed with cores in the tubes. Trouble developed almost immediately when these were put into service due to eccentricity of cores and uneven distribution. Cores were subsequently removed and distributing plugs, or nozzles, put into the inlet ends of all tubes. Troubles were greatly reduced with this arrangement. Plugs were selected that would give approximately the same pressure drop through the superheater as experienced with the core.

No. 37 to 40, inclusive, were originally set up with neither cores nor distributing nozzles. The pressure drop on these was very slight and no trouble developed from poor distribution and overheating for about a year at which time tube failures began to be of very frequent occurrence, and in practically every case evidence pointed toward overheating. Here, again, distributing plugs were resorted to, with favorable results.

The superheaters of boilers No. 41 to 47, inclusive, except No. 44, were originally set up with distributing plugs inserted into the inlet ends of all tubes and very little trouble has been experienced since their installation. None of the little trouble we have had could be definitely laid to poor distribution.

In operation all four types obviously lose heating effect with collection of refuse from oil fire. Proper installation and application of soot blowers removes the greater part. However, in the case of the cast iron fin covered tubes, cleaning is done with a great deal more difficulty than in the case of smooth tubes. Moreover, a quantity of the deposit collected between the fins is practically unremovable and remains as a permanent detriment to heat absorption until cleaned by washing with a high pressure stream of water. No other means has proved to be more than merely a partial relief. Superheaters of this type will accumulate soot and sodium sulphate from the oil fires in a comparatively short time so that the spaces between tubes are so

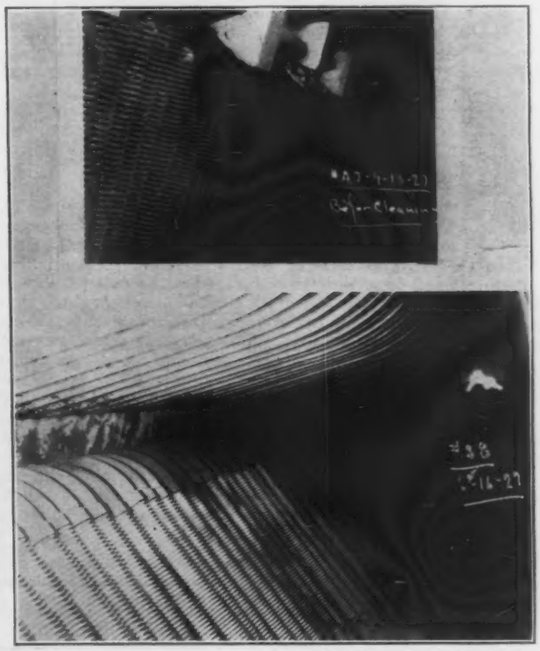


Fig. 13. (Below) Another position of the same make of superheater as that shown in Fig. 12. All accessible parts have been thoroughly cleaned after wedging tubes apart to permit the passage of an air lance between the tubes. In spite of heroic efforts at cleaning this superheater failed to give more than 50 per cent of the superheat that it gave when new.

filled that gases of combustion cannot pass through the superheater at all, but pass around it, giving up heat to only a small portion of the surface.

On boilers with this type of superheater with soot blowers not installed inside the loops, it was found impossible to clean them with air lanes sufficiently to get the required superheat. It was necessary to resort to the washing method mentioned.

Smooth, bare tubes do not accumulate residue so rapidly and never get into such bad condition from dirt, etc., as the fin tube type and are more easily cleaned. Fluctuations in steam temperature, however, with varying conditions are more rapid, the heavy cast iron fins acting as heat reservoirs and smoothing out the fluctuations.

No. 4 boiler superheater sprung a few leaks at the

TABLE VIII.

Boiler Rating	B.H.P.	Gas, Lb. Per Hr.	Air, Lb. Per Hr.	Gas Inlet Temperature
100%	1,500	61,900	58,200	345 deg. F.
200%	3,000	127,500	120,000	415 deg. F.
300%	4,500	194,000	182,000	485 deg. F.

Temp. Drop	Final Gas Temp.	Air Inlet Temp.	Rise Air Temp.	Final Air Temp.	Draft Loss Air	Draft Loss Gas
162 deg. F.	183 deg. F.	75 deg. F.	155 deg. F.	230 deg. F.	0.10 in.	0.10 in.
175 deg. F.	240 deg. F.	75 deg. F.	167 deg. F.	242 deg. F.	0.39 in.	0.37 in.
195 deg. F.	290 deg. F.	75 deg. F.	186 deg. F.	261 deg. F.	0.90 in.	0.95 in.

ball joints between the tubes and header due to bearing of parts of the housing against the tubes and throwing them out of true. This was easily remedied by removal of the offending parts of the housing. After about fifteen or sixteen months of service the supporting and spacing members for the lower ends of the tube loops burned out and left the tubes to sag and be thrown out of true at the ball joints. Repeated attempts to repair the leaks were unsuccessful and electric and gas welding were even resorted to unsuccessfully. Replacing of the supporting members on the tube loops and reconditioning the ball joints made a good job of it. In making repairs to ball joints many of the nuts on the studs holding the yokes in place froze and it was necessary to drill the studs out of the header, causing trouble and delay.

Water Cooled Walls—Water walls are installed in seven bent tube types 1,500 boiler horsepower boilers. The boilers are fired with combination gas and mechanical atomizing oil burners.

There are 936 sq.ft. of water wall surface in each boiler, to-wit: Front wall 586 sq.ft. and each side wall 175 sq.ft., there being none in rear or bridge wall. The ratio of water cooled surface to boiler heating surface is approximately one to sixteen.

The front water wall is composed of 50 tubes 21 ft. 4 5/16 in. long, connecting the front boiler steam drum to the front water wall header, also one additional tube from the header venting into the front steam boiler drum. Each side wall is composed of 23 tubes 16 ft. 3 in. long connecting an upper and lower water wall header. Also there are four recirculating tubes connecting each upper side wall header to the middle steam drum; therefore, each wall has a complete water circulation. Water is supplied to the lower headers of the water walls from the boiler mud drum, nipples being projected into the interior of mud drum a sufficient distance to eliminate the danger of passing sediment from mud drum to water walls.

The tubes of the front water screen are spaced to 6-in. centers and are recessed in special tile so that about one-fourth of the circumference of the tube is exposed to the radiant heat excepting the lower 16 in. on furnace side, which is protected by the special refractory block, also tubes number 1 and 50 are protected by the block. The tubes of the side wall water screen are spaced to 6-in. centers and are protected by the blocks.

The block is a cast iron refractory faced block about 6 x 8 in. and is fastened to the tube by means of a clamp attached to a stud on back of block. A special conducting cement is used for cementing the blocks to the tubes. All water screen tubes are No. 6 B & W gage 3¼ in. outside diameter. There has been no tube trouble experienced except leaks at rolled joints and gasket connections of handhole plates and flanges. There has been no difficulty with the boiler setting due to water wall except tendency towards air infiltration at seals which is remedied by alterations and improvements in methods of sealing.

Air Preheaters—Tubular type air preheaters are installed with seven bent tube type boilers. The air heater external heating surface is 16,400 sq.ft., internal 14,850 sq.ft. It contains 2,280 tubes, 11 ft. long, 2½ in. outside diameter and No. 12 gage. The gas passage area is 6.34 sq.ft. per boiler horsepower, the air passage area being 3.06 sq.ft. per boiler horsepower, making a total gas passage area of 9,510 sq.ft. and a total air passage area of 4,590 sq.ft. Each one is located in the path of the flue gases, after the economizer and before the induced fan, the air passage being on the inside and gas on the outside of tubes, counter flow.

The preheater tubes are cleaned on outside 1,500 to 2,000 operating hours by means of hose wash-down from top, requiring about 30 min. for two men.

There have been no tube failures, but slight corrosion at cold air inlet on outside of tubes has been noticed where tubes may have been cooled to the dew point of gases.

Table VIII gives performance guarantee data.

Statement of Pacific Gas and Electric Company

This company is installing two boilers at Station C, Oakland, in connection with a 37,500-kw. turbine, one

TABLE IX—Performance data of $\frac{51-24}{60}$ 24 boiler with interdeck superheater and a 51,232 sq. ft. air heater when fired with fuel oil mechanical burners

Evaporation includes wall evaporation.

	Pounds of steam per hour, actual					
	150,000	200,000	250,000	300,000	350,000	425,000
Drum steam pres., lb. per sq. in.	450	450	450	450	450	450
Degrees superheat, F.	235	247	256	264	269	274
Per cent CO_2 leaving boiler	14	14	14	14	14	14
Per cent CO leaving boiler	0	0	0	0	0	0
Temp. of flue gas leaving boiler, degrees F.	500	525	560	595	635	700
Temp. of flue gas leaving A. H., degrees F.	237	256	277	298	319	353
Temp. of air entering A. H., degrees F.	80	80	80	80	80	80
Temp. of air leaving A. H., degrees F.	397	404	421	438	460	498
Eff. of boiler S. H. and furnace, per cent	80.5	79.9	79.1	78.3	77.4	75.9
Eff. of boiler A. H. and furnace, per cent	86.6	86.1	85.6	85.1	84.7	83.9
Draft loss through boiler, in. of H_2O	.38	.68	1.08	1.59	2.20	3.32
Draft loss through A. H., in. of H_2O	.28	.51	.81	1.19	1.64	2.47
Air resistance through A. H., in. of H_2O	.35	.64	1.01	1.49	2.06	3.10
Pounds of flue gas per hour	159,800	215,100	271,800	329,500	388,000	476,300
Pounds of air through A. H. per hour	143,100	192,600	243,500	295,200	347,400	426,600
Temp. of feed water, degrees F.	365	365	365	365	365	365
Pres. drop drum to S. H. outlet, lbs. per sq. in.	4	7	11	15	20	29

Flue gas temperature will be about 475 degrees F. when evaporating 40,000 lbs. of steam per hour.

OIL ANALYSIS

Carbon	88.43
Hydrogen	10.27
Oxygen	0.22
Nitrogen	0.36
Sulphur	0.72
B.T.U. per lb., 18,500. Total	100.00

boiler being required to operate the turbine and the other being a spare. These boilers are the largest boilers built to date for power purposes.

Each boiler is of the cross drum type, having a total heating surface of 35,453 sq.ft. Each boiler will consist of 51 sections arranged in three decks, 9, 10, and 5 tubes respectively, made up of 4-in. No. 6 gage seamless steel tubes, expanded into wrought steel headers. Each section will be 24 tubes high and have tubes 24 ft. long. The drum will be 60 in. in diameter and 34 ft. 2¾ in. long. The boilers will be constructed for 460-lb. maximum working pressure in the drum. The center line of the boiler drum is 46 ft. 8 in. above the floor line giving 25 ft. setting height under the front headers. This gives a furnace volume of 14,600 cu.ft.

Each boiler will have a convection type quadruple deck, three-pass superheater located just above the first five boiler tubes. The superheater tubes will be 2-in. hot finished seamless steel tubes, No. 10 B.W.G. Superheater headers are 15-in. inside diameter seamless steel tubes. Superheater heating surface is 6,553 sq.ft. Each boiler will have an air preheater of the tubular type having 2,176 2½-in. No. 11 B.W.G. hot finished seamless steel tubes, 36 ft. long, having a total external heating surface of 51,323 sq.ft. and an internal surface of 46,350 sq.ft.

There will be water walls furnished in each furnace having a surface of approximately 1,674 sq.ft. All furnace wall tubes will be 3¼ in. outside diameter No. 6 B.W.G. installed on 6-in. centers and circulating tubes will be the same diameter, but No. 7 B.W.G. All furnace wall tubes will be fitted with refractory faced blocks.

These boilers will probably be placed in operation the later part of June. The accompanying diagram shows the arrangement of the boiler, airheater, etc.

Table IX gives the expected performance of the boilers described in the foregoing paragraphs.

Boiler Feedwater Treatment*

The committee on boiler feedwater treatment has attempted a survey of member companies to determine if possible those that are having feedwater trouble, of what nature, the remedies applied and the results obtained so that companies having similar feedwater conditions may profit by such experience.

To obtain this information a questionnaire was sent to each member company known to have steam plants. The questionnaire together with answers is made a part of this report. In this connection it was thought advisable to obtain analysis of make-up, feedwater, treated water and circulating water. These also are included.

It is of interest to note that out of eleven plants reporting, all but one are using some kind of feedwater treatment, and that none **now** are having any trouble due to scale, corrosion, or caustic embrittlement although it is known that several have experienced trouble in the past.

The various treatments used are the lime soda, zeolite softeners, boiler compound, evaporators and the combination of water softeners and evaporators and also the use of sodium sulphate or sulphuric acid in order to maintain the proper sulphate-to-carbonate ratio in the boilers.

The Southern California Edison Company uses zeolite softeners to soften water to the evaporators at Long Beach steam plant and found it necessary to add sulphates to boiler feedwater in order to maintain the proper ratio of sulphate-to-carbonate to prevent caustic embrittlement. It was found impossible to add sufficient sulphate or sulphuric acid to maintain the proper ratio without the formation of calcium sulphate scale. This difficulty has been overcome by adding sodium sulphate and half its weight of tri-sodium phosphate. With this combination the desired ratio is maintained easily.

The Los Angeles Gas and Electric Corporation's Alameda St. station stands unique. All of the water both for condenser circulation and boiler feed first is put through a zeolite softening process. Inasmuch as the cooling water of this plant passes repeatedly through cooling towers the concentration of salts becomes very high with the result that condenser leakage will cause an excessive amount of carbonates to be present in the boiler water. To eliminate this the pond water was treated with sulphuric acid so that all water would be of the proper ratio no matter from what source it entered the boilers. A more detailed report of this is given later on.

It would appear from the replies received that there is no definitely fixed boiler concentration that should be allowed, but that each operator stops at some point, above which priming would be expected. It is obvious that the concentration of sulphates or carbonates may be of any value from zero to many grains per gallon. As long as a certain hypothetical fixed ratio is maintained between sulphate and carbonate no serious consequences are to be expected. It also is a well known fact that though large quantities of acid or alkali be present they are active only to the extent they are ionized. In many industries it has become of exceeding importance to control the acid or "H" ion concentration commonly expressed as the "pH" value of their solutions. Should any hydrogen-ion control of boiler water

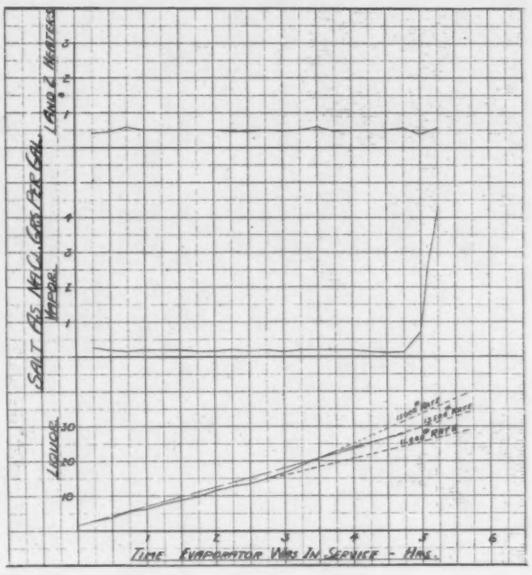


Fig. 1. Salt test on evaporator No. 1-B at Seal Beach plant.

be attempted, the "pH" values should be determined if possible under operating conditions of temperature and pressure. It would seem that this is something to which power companies should give serious consideration and study.

The experience of the Los Angeles Gas and Electric Corporation at Seal Beach plant is of interest. Well water is evaporated for boiler make-up. This well water contains about eight times as much carbonates as sulphates. Since some salts are carried over in the vapors from the evaporators the result is a building up of too high a carbonate concentration. The circulating water is taken from the bay which has about 28 times as much sulphates as carbonates. With excessive leakage from the condenser a high sulphate concentration is built up. However, by keeping the condenser leakage small a 3-to-1 ratio can be maintained.

Accompanying curves throw some light upon evaporator performance. Checks were made for sodium chloride only. The curve at the top is from a mixture of the condensate and water condensed from the evaporator. The curve in the center shows salt in the vapor. The curve at the bottom shows the rate at which the evaporator was fed water and the concentration of salt in the liquor. It is to be noted that there is no gradual increase of salts in the vapor when the liquor concentrations are allowed to increase. The abrupt change marks the point at which the evaporator begins to prime.

From the information at hand it would appear that to avoid trouble from scale, corrosion, or embrittlement all water fed to boilers should be evaporated and the air removed by vacuum. A daily check should be made of boiler water and a proper ratio of sulphate to carbonate maintained. This possibly could be accom-

* Report of subcommittee of prime movers committee.—F. R. night, chairman.

TABLE II—Questionnaire Concerning Boiler Feedwater

QUESTIONS	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6	Company 7	Company 8	Company 9	Company 10	Company 12
Are you troubled with:											
(a) Scale	No		Light	No	Not for 3 years	Yes	Slight	No	Some from water treatment	Little	No.
(b) Corrosion	Very little		Some	No	Slight	No	Slight; none now	No	No	No	In economizer sections.
(c) Caustic embrittlement	No		No	No	No	No	Yes; necessitat. renewal	No	Treat to prevent caustic embrit.	No	Yes.
(d) Other feed water troubles	None		No	No	Sludge	None	None	None	None	No	Some air.
Do you treat feed water	Yes		No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes.
(a) For what purpose	Prevent scale and corrosion			Prevent scale and corrosion		Eliminate scale.	Softening removal of increasing sulphate	Prevent pitting and corrosion	Prevent caustic embrittlement.	Softening	To maintain sulphate carbonate ratio which inhibits its caustic embr.
(b) What treatment used	Hydrate lime and soda ash					Lime and soda; not process	Permutit, open heater, increase sulphate	Boiler compound	Sodium sulphate with half tri-sodium phosph	Zeolite	Zeolite; sulphuric acid.
(c) What results	Fair			Good		Fair	Very good	Good	Good	Good	Ratio is maintained but the results will depend upon time
Any trouble experienced from use of treatment	Small deposit of lime in tubes in mud drum			No		Scale not all eliminated	No	None; overdose causes priming	Not at present	No	No.
How long used	Since 1917			3 years		7 years	Permutit, 5 years Sulphate, 1¼ years	7 years	Very recent	7 years	Zeolite since 1922 Sulphuric acid, May, 1927.
Cost of treatment in cents per 1,000,000 lbs. water evaporated	0.62					$2.55 chemicals and labor	$1.43, not including labor		$0.002	$3.00	Acid, $0.46 per Million. Softening, $5.00 per Million.
Do you make your own water analysis	Yes		Yes	Yes	No	No	Yes	Partial.*	Yes	No	Yes
Do you test for:											
(a) Chlorides	Yes		Yes	Yes	Yes		Yes	Yes	Yes (daily)	No	Yes.
(b) Carbonates	Yes			Yes	Yes		Yes	Yes	Yes (daily)	Yes	Yes.
(c) Sulphates				Yes	Occasionally	Yes			Yes (special)	No	Yes.
(d) Hydroxides				Yes	Yes		Yes		Yes (daily)	No	Yes.
(e) Or what	Total concentration			Total solids		Causticity, alkalinity, hardness, chlorine			Oxygen after deaerator		
Are tests made:											
(a) Daily	Yes			Yes	Yes	Yes	Yes		Yes	Yes	Pond water, 3 times a week; 2 boilers tested daily.
(b) Weekly			Yes								
(c) Monthly											
Do you use evaporators	No		No	Yes	No	No	No	No	Yes	No	Yes.
Are heaters open or closed	Open		Open	Closed	Open	Closed	Open and closed	Open	Closed	Open	Open.
Do you use deaerators	No		No	Heaters are deaerators	No	No	No	No	Yes	No	Yes.
What is cir. water taken from		San Fran. Bay	Sea water in Harbor	Alamitos Bay	San Fran. Bay	San Fran. Bay	San Diego Bay	Bakersfield River Midway—deep wells	Sea water in harbor inlet	Wells	Cooling pond.
What is make-up water taken from	Well	San Fran. city water	Surface water reservoir	Deep well	Own wells	City water	City water	Deep well	Well water	Wells treated	City water after Zeolite treat. is fed to cooling pond. Treat. with sulph. acid.
Give make of boilers	B. & W. Stirling		Stirling Class 30	B. & W.	B. & W. Stirling	B. & W. Stirling	B. & W.	Stirling Connelly's	4 B.&.W. Stirling. 11 Connelly	Stirling	Stirling.
Size in HP	768		822.6	2,540	525 to 823	524 to 890	1,153	822 and 824	1,500	500	890.
Total operating hours	Irregular		720			44,675.5 (1927)	30,087 (1927)		1,000-2,000		
Rating at which operated—%	0-400		150	260		80% in 1927	Avg. 160, Max. 360	Avg. 150	280-300	100	75.
Pressure at which operated—Lb. gage	250		300	385	200 to 250	200	240	250 to 260	385	200	250.
Give normal concentration of salt allowed—Gr. per U. S. Gal	100		90	30		200	100	200 NaCl	50 chloride	234	See note below.
Max. alkalinity as sodium carbonate allowed—Gr. per U. S. Gal	30			Ratio 3 to 1			Not specified; Actually over 100		Ratio 3 to 1	234	50.
Are boilers calked:											
(a) Inside				Yes		No	Yes		Yes	No	
(b) Outside	Yes		Yes		Yes	Yes	Original outside replaced	Yes	No	No	Yes.

NOTE: The salt concentration is of no value except in determining total solids and what they are. The concentration of other compounds builds up to such an extent that their elimination keeps the salt concentration down.

TABLE I—Questionnaire Concerning Boiler Feedwater—Continued

QUESTIONS	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6	Company 7	Company 8	Company 9	Company 10	Company 12
Are boiler drums painted	No		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Some are.
(a) With what			Apexior	Apexior	Spartan	Spartan	Apexior	Steam space kerosene and zinc. Water space keros. & graph.	Apexior	Graphite. Vegetable oil	Apexior
WATER ANALYSIS											
Raw water—Gr. per U. S. Gal.:											
(a) Suspended matter	1.44	None		Organic 0.07 none		Organic 1.26-0.11	0.044		Trace		None.
(b) Silica	0.44	0.56	0.233	1.05	1.458	1.35	0.467	1.44	0.7	1.330	0.12.
(c) Iron Oxide and Alumina	0.44	0.08	0.186	0.30	0.175	0.03	0.186	0.12	0.23	0.233	0.05.
(d) Calcium Sulphate	1.00	None	0.047	Trace	Calcium bicarb.	1.48	0.000	0.41	0.00	0.000	Trace.
(e) Calcium Carbonates	5.38	5.90	0.923	0.91	2.006	Calcium bicarb. 6.15-0.57	4.672	1.42	4.08	5.185	9.94.
(f) Calcium Chloride		None		None	3.644				None		None.
(g) Magnesium Carbonate	5.26	2.42	1.167	0.17	Calcium bicarb. 7.575	Mag. bicarbon. 6.56	2.848	0.12	2.44	2.070	0.29.
(h) Magnesium Sulphate		1.48		None				0.14	0.15		2.99.
(i) Magnesium Chloride		None		None					None		None.
(j) Sodium Carbonate		None		8.74			1.101	1.38	5.70	2.920	0.90.
(k) Sodium Sulphate		0.71	0.478	1.06	1.848	0.90	1.264	2.69	2.84	1.746	7.12.
(l) Sodium Chloride	1.70	1.83	2.380	1.73	9.710	2.10	6.800	6.89	5.79	1.020	2.89.
(m) Sodium Nitrate	Undetermined, 1.77	0.21	Trace				Trace	Volatile and organic, 3.27		Trace	None.
(n) Sodium Hydroxide		None									None.
(o) Total solids	17.83	13.19	6.073	13.96		20.52	17.286	17.88	29.77		24.30.
Uncombined c.c. per liter:											
(a) Carbon Dioxide		0.04		None							0.29.
(b) Hydrogen Sulphide		None		None							None.
(c) Oxygen		0.52		P H 8.5							0.15.
Feed water—Gr. per U. S. Gal.:											
(a) Suspended matter		None				Organic 0.25	0.18				None.
(b) Silica		0.16				0.53	0.28				0.07.
(c) Iron Oxide and Alumina		0.06				0.05	0.02				None.
(d) Calcium Sulphates		None									None.
(e) Calcium Carbonate		1.71				Bicarbonate trace	0.12				Trace.
(f) Calcium Chloride		None									None.
(g) Magnesium Carbonate		1.00				Bicarbonate, 2.14	Trace				Trace.
(h) Magnesium Sulphate		None				0.42					None.
(i) Magnesium Chloride		None									None.
(j) Sodium Carbonate		0.77					3.51				0.35.
(k) Sodium Sulphate		0.74				0.22	0.15				1.24.
(l) Sodium Chloride		0.78				2.04	1.75				0.50.
(m) Sodium Nitrate		Trace									None.
(n) Sodium Hydroxide		None				0.00					None.
Total Solids		5.22				5.65	6.86				2.16.
Uncombined c.c. per liter:											
(a) Carbon Dioxide		None									None.
(b) Hydrogen Sulphide		None									None.
(c) Oxygen		0.05		0.00							0.12.
Remarks			Boilers are equipped with Tracy-fiers which keep concentration below 50 gr.	See remarks							
Cir. water—Gr. per U. S. Gal.:											
(a) Suspended matter		5.72		Organic 2.98 Filtered				0.00	Trace		
(b) Silica		0.54		0.82				0.43	0.46		3.91.
(c) Iron Oxide and Alumina		0.56		0.58				0.12	0.35		0.18.
(d) Calcium Sulphate		63.02		69.65				1.66	77.16		Trace.
(e) Calcium Carbonate		6.31		7.30				1.13	5.60		2.25.
(f) Calcium Chloride		None		None				0.00	None		None.
(g) Magnesium Carbonate		None		None				0.45	1.42		0.86.
(h) Magnesium Sulphate		109.56		126.90				0.23	124.22		None.
(i) Magnesium Chloride		171.69		182.20				0.00	185.4		None.
(j) Sodium Carbonate		None		Trace				1.12	Trace		38.40.
(k) Sodium Sulphate		None		None				1.30	None		127.00.
(l) Sodium Chloride		1,359.96		1,532.00				0.19	1,608.2		41.78.
(m) Sodium Nitrate		None						Volatile and organic, 4.59			None.
(n) Sodium Hydroxide		None									None.
Total Solids		1,717.36		1,919.45				11.22	2,312.8		214.38.

NOTE.—The salt concentration is of no value except in determining total solids and what they are. The concentration of other compounds builds up to such an extent that their elimination keeps the salt concentration down.

TABLE I—Questionnaire Concerning Boiler Feedwater—Continued

QUESTIONS	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6	Company 7	Company 8	Company 9	Company 10	Company 12
Uncombined c.c. per liter:											
(a) Carbon Dioxide		None		None							None.
(b) Hydrogen Sulphide		None		None							None.
(c) Oxygen		0.44		2.98							0.21.
Treated water—Gr. per U. S. Gal.:											
						(Susp. 0.82.					
						(Org. 1.17	0.698		Filtered	0.994	None.
(a) Suspended matter		None				2.32	0.747		1.17	0.350	0.07.
(b) Silica		0.24				0.04	0.210		0.07	None.	None.
(c) Iron Oxide and Alumina		0.04					0 000		0.22	None.	None.
(d) Calcium Sulphate		None				1.13	0.834		3.96	0.570	Trace.
(e) Calcium Carbonate		0.33							None.		None.
(f) Calcium Chloride		None							3.26	0.495	None.
(g) Magnesium Carbonate		0.29				MgOH 0.12	0.159		None.		None.
(h) Magnesium Sulphate		None							None.		None.
(i) Magnesium Chloride		None							11.53	11.358	11.47.
(j) Sodium Carbonate		3.51				2.16	8.306		2.18	1.990	10.30.
(k) Sodium Sulphate		0.16				2.04	0.878		6.07	3.740	3.18.
(l) Sodium Chloride		0.48				2.10	6.800				None.
(m) Sodium Nitrate		None					0.205				None.
(n) Sodium Hydroxide		None				1.68	0.000		23.86		25.02.
Total Solids		5.05				11.42	18.337				
Uncombined c.c. per liter:											0.17.
(a) Carbon Dioxide		None									None.
(b) Hydrogen Sulphide		None									0.26.
(c) Oxygen		0.08									

NOTE.—The salt concentration is of no value except in determining total solids and what they are. The concentration of other compounds builds up to such an extent that their elimination keeps the salt concentration down.

plished by treating the water to the evaporators. If not, by direct additions to the boiler make-up.

Report on Feed Water Treatment at Alameda Street Station, Los Angeles Gas and Electric Corporation

In February, 1927, during the regular cleaning and inspection of boiler No. 31 a leak was found around a rivet in the mud drum butt-strap which could not be caulked. In attempting to caulk this rivet the rivet backed out of the hole showing that it was broken somewhere between the heads.

Boiler No. 31 is one of 14 Stirling boilers, Class 13, 8,900 sq.ft. of heating surface and operated at 250 lb. per sq.in. gage pressure. Upon investigation it was found that 23 rivets were broken. It was decided to remove the butt-straps on this mud drum to see if any further damage to the steel had occurred. Fine cracks between the rivet holes opened up after a drift pin had been driven through the rivet holes. The accompanying illustration shows the location of the rivets and cracks as found.

All 14 of the boilers have been inspected during the past year and 8 have been affected to some extent the same as No. 31 boiler. This trouble is claimed to be caustic embrittlement by the builders of the boilers.

The manufacturer advised that something be done to get the ratio of the sulphates to the hydroxides in the boilers to 3-to-1. Analysis is given here of the water in this station from the source to the boilers.

The circulating water for the condensers to the main generating units is pumped over a cooling tower. This water is used over and over. To avoid scale in the condenser tubes, a water softening plant is used to remove the calcium hardness from the make-up water to the towers. As the evaporation from the towers is high the concentration of the solids is high and runs about 300 gr. per gal. This water due to condenser leakage gets into the condensate which is returned to the boilers. This leakage is very slight as may be noted from the analysis sheets of the feedwater. The make-up water for the boilers is distilled in two "double-effect" evaporators. The water to the evaporators was softened city water from the softeners.

Prior to the discovery of the caustic embrittlement, the ratio of the sulphates to the hydrates in the boilers was approximately 1.5 to 1. If the sodium carbonate also is an inhibitive to caustic embrittlement, the ratio of sulphate-plus carbonate to hydrates was about 2 to 1.

In order to maintain an average ratio of 3 to 1 of sulphate to hydrates, the sodium sulphate first was added to the water in the boilers. It was thought that the sodium sulphate upon being added to the water in the boilers would prevent the sodium carbonate from breaking down into sodium hydroxide. The quantity of sodium sulphate used under the load conditions under which the plant was operating was about 536 lb. per day. The water fed to the boilers contained 1.23 gr. per gal. of sodium carbonate and only a trace of sodium sulphate. The additon of 3 gr. per gal. of sodium sulphate was sufficient to give a 3-to-1 ratio of sulphate to carbonate. The average amount of water fed per week-day was about 10,000,000 lb., or 1,250,000 gal. at 200 deg. F.

However, the sodium sulphate did not prohibit the carbonate from breaking down into hydroxide. Also it was found difficult to control the ratio in all the boilers as it meant two water analyses for each boiler every day. A chemist then in consultation with the company suggested that the water be treated in the cooling towers with sulphuric acid, and also use the water from the towers to the evaporators. In this way the carbonate in the towers was changed to sodium sulphate and as the ratio was correct, condenser leakage or evaporator throw-over would be of no consequence. The following shows how the calculation was made to get the ratio desired, and the quantity of acid used:

Treating Pond Water With Sulphuric Acid

Relative to treating the pond water with sulphuric acid, the known and probable reactions are given here:

From a chemical analysis dated March 4, 1927, the pond contained 299.32 gr. per gal. of troublesome solids. Of this, 115.85 gr. sodium carbonate (Na_2CO_3), 110.40 gr. sodium sulphate (Na_2SO_4), 72.95 gr. sodium chloride (NaCl), and 0:12 gr. calcium chloride ($CaCl_2$).

It is assumed in treating this water with sulphuric acid (H_2SO_4) that only the sodium carbonate will react to form sodium sulphate. Thus the equation

$$H_2SO_4 + Na_2CO_3 \longrightarrow H_2O + CO_2 + Na_2SO_4$$

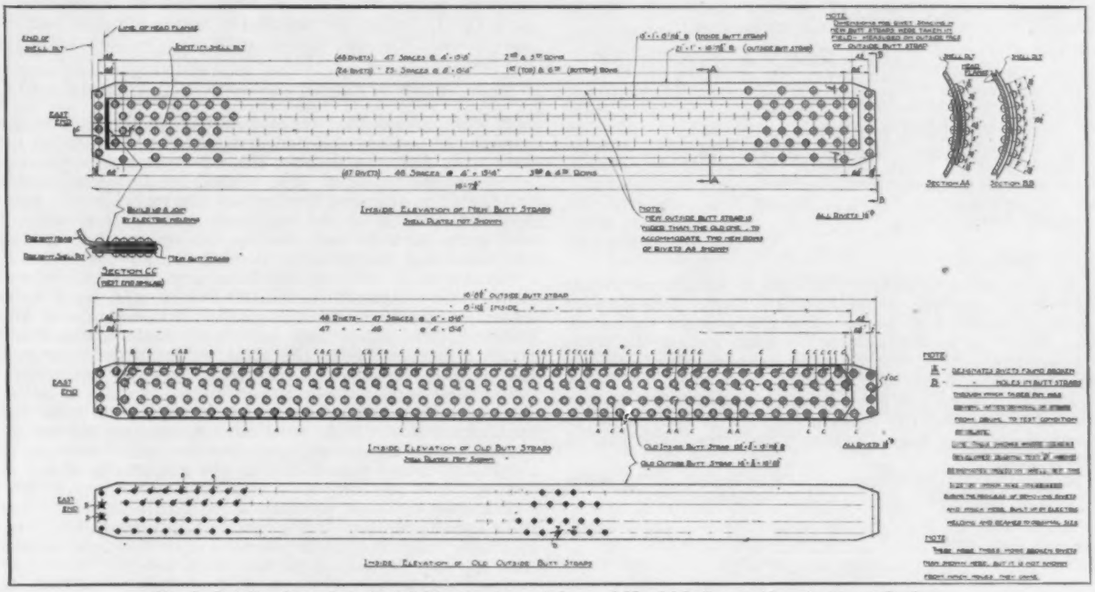


Fig. 2. Details of repair to back butt-strap in mud drum of No. 31 boiler at Alameda Street Station.

This assumption will remain a fact so long as not all of the sodium carbonate is reduced to sodium sulphate. In the event that there is not immediately enough sodium carbonate to react with the acid as fed, the sodium chloride and calcium chloride both will react as in the following equation:

$$H_2SO_4 + 2NaCl \longrightarrow 2HCl + Na_2SO_4$$
$$H_2SO_4 + CaCl_2 \longrightarrow 2HCl + CaSO_4$$

It may be noted that in both of these equations there is formed hydrochloric acid (CHl). This would cause considerable trouble, but fortunately as the acid comes in contact with more water in the pond the hydrochloric acid will react with the sodium carbonate, as in the following:

$$2HCl + Na_2CO_3 \longrightarrow 2NaCl + H_2O + CO_2$$

The calcium chloride will react in the same way leaving hydrochloric acid and calcium sulphate. However, the final result will be the same as though the sulphuric acid had not attacked the sodium chloride. The fundamental equation still is:

	$H_2SO_4 + Na_2CO_3 \longrightarrow$	$H_2O + CO_2 + Na_2SO_4$
Atomic weight	1-32-16 23-12-16	1-16 12-16 23-32-16
Combined atomic weights	98 + 106 =	18 + 44 + 142

From the above it may be noted that 98 lb. of sulphuric acid (100 per cent) will react with 106 lb. of sodium carbonate to form 18 lb. of water, 44 lb. of carbon dioxide (CO_2) and 142 lb. of sodium sulphate (Na_2SO_4).

This shows that for 1 lb. of sodium carbonate completely deduced,

$$\frac{142}{106} = 1.34 \text{ lb. sodium sulphate results}$$

From analysis there is 115.85 gr. of sodium carbonate and 110.40 gr. of sodium sulphate per gal. of pond water. Inasmuch as there is some sodium sulphate present this must be taken into consideration to get the proper final ratio of three parts of sulphate to one part carbonate.

Let X = the amount of carbonate to be reduced to bring the sulphate-carbonate ratio up to 3 to 1.

Equation:
$$\frac{1.34X + 110.40}{115.85 - X} = \frac{3}{1}$$
$$= 1.34X + 110.40 = 347.55 - 3X$$
$$= 3X + 1.34X = 347.55 - 110.4$$
$$= 4.34X = 237.15$$
$$= X = \frac{237.15}{4.34} = 54.643$$

It is necessary therefore to reduce 54.643 gr. per gal. of sodium carbonate to sodium sulphate to get the required ratio. This ratio in gr. per gal. being 183.63 of sodium sulphate and 61.21 of sodium carbonate.

The combining ratio of the sulphuric acid and sodium carbonate is 98 to 106. In other words, for 1 lb. of sodium carbonate to be reduced with sulphuric acid it requires 0.02453 lb. of acid. It is necessary then to use $54.643 \times 0.92453 = 50.519$ gr. per gal. of 100 per cent sulphuric acid to get the proper ratio. However, commercial acid which is used is of 63 deg. (Beaume) gravity which corresponds to 83 per cent purity. 50.519 gr. per gal. is only 0.83 of the amount required, so that the amount of commercial acid needed is 60.866. gr. per gal.

The reservoirs contain the following amounts of water:

No. 3	150,000	gal.
No. 4	741,000	gal.
No. 5	747,800	gal.
No. 6	985,400	gal.
No. 7	915,300	gal.
No. 8	914,790	gal.
No. 9	539,700	gal. (calculated)
Total	4,993,990	gal.

As this is approximately 5,000,000 gal. the acid required will be calculated on the basis of 5,000,000 gal.

From the previous calculation 60.866 gr. of the 63 deg. (Beaume) acid per gal. of water will be required to gain the proper ratio.

$$\frac{5{,}000{,}000 \times 60.866}{7{,}000 \text{ (gr. per lb.)}} = 43{,}475.7 \text{ lb.}$$

43,475.7 lb. of acid required to bring the sulphate carbonate ratio to 3 to 1. This is 21.737 tons of 63 deg. (Beaume) acid.

In order to maintain the desired ratio in the pond and add make-up water it is necessary to treat the water with sulphuric acid. The make-up water which is from softeners contains the following solids, from analysis dated March 7, 1927:

Sodium carbonate	11.47 gr. per gal.
Sodium sulphate	10.30 gr. per gal.
Sodium chloride	3.18 gr. per gal.

The ratio desired being three parts of sulphate to one of carbonate.

Reaction: $H_2SO_4 + Na_2CO_3 \longrightarrow H_2O + CO_2 + Na_2SO_4$

Let X = the amount of sodium carbonate to be treated to give the proper final ratio, then:

$$\frac{1.34X + 10.30}{11.47 - X} = \frac{3}{1}$$

$$= 1.34X + 10.30 = 34.41 - 3X$$
$$= 1.34X + 3.00X = 34.41 - 10.30$$
$$= 4.34X = 24.11$$
$$= X = \frac{24.11}{4.34} = 5.555$$

It is required to reduce 5.555 gr. of sodium carbonate to sodium sulphate, using sulphuric acid. The amount of acid required to react with the sodium carbonate was found to be 0.92453 to 1. 5.555 sodium sulphate times 0.92453 = 5.13576 or 5.136 gr. per gal. of 100 per cent sulphuric acid. As the acid to be used is 63 deg. (Beaume), or 83 per cent, it will require 6.188 gr. per gal. of water fed for make-up. This is equivalent to 0.884 lb. of 63 deg. (Beaume) acid to 1,000 gal. of water fed.

If it is wanted to change the ratio to two of sulphate to one of carbonate, the equation becomes:

$$\frac{1.34X + 10.30}{11.47 - X} = \frac{2}{1}$$

$$1.34X + 10.30 = 22.94 - 2X$$
$$1.34X + 2X = 22.94 - 10.30$$
$$3.34X = 12.64$$
$$X = 3.7844$$

The amount of sodium carbonate to be treated to form sodium sulphate is then 3.7844 gr. per gal. of water from the softener. Acid required is 0.92453. Then $0.92453 \times 3.7844 = 3.4987$ or 3.50 gr. of 100 per cent acid per gal. of water. This is equivalent to 0.5 lb. of acid per 1,000 lb. of water from the softener to maintain a 2-to-1 sulphate-carbonate ratio, or 0.602 lb. of 63 deg. (Beaume) sulphuric acid.

In stating that the resultant reaction is the same when water containing both sodium carbonate and sodium chloride is treated with sulphuric acid and some of the carbonate is permitted to remain as though no sodium chloride were present, it is better explained in the following:

Assume the treament of a definite quantity of water such as the pond water with sufficient acid to react with both the sodium carbonate and the sodium chloride. This reaction would be:

$$H_2SO_4 + \begin{cases} Na_2CO_3 \longrightarrow H_2O + CO_2 + Na_2SO_4 \\ 2NaCl \longrightarrow 2HCl + Na_2SO_4 \end{cases}$$

If this definite quantity of water were 1,000 gal. and treated as shown in the above reaction, the solids would change to water, carbon dioxide gas, sodium sulphate and hydrochloric acid. Now without the addition of further sulphuric acid, add 1,000 gal. of untreated water to the treated water. Then there is in the treated water the active compound of hydrochloric acid (HCl) and in the untreated water alkaline sodium carbonate. The sodium chloride and sodium sulphate are neutral salts.

Then, $2HCl + Na_2CO_3 \longrightarrow H_2O + 2NaCl + CO_2$.

It may appear that there would be an increase in the amount of sodium chloride, but this is not the case, for this is in fact the sodium chloride which was reduced by the sulphuric acid. The reason for this explanation is that when the acid first enters the water it will unite with everything at the beginning and as it spreads it will come back to the reaction desired so long as the entire pond is permitted to contain sodium carbonate.

On April 22, 1927, 43,480 lb. of acid was put into the pond. Since that time, 60,800 lb. of acid have been added at intervals as necessary. An analysis of the water in the ponds and boilers is made about three times a week. Due to the large volume in storage and the small per cent which forms the make-up, the chemical change of the water is very slow; that is, in building up sodium carbonate which is carried in with the make-up water. It is very easy to control the entire system and the sulphate-carbonate ratio always is somewhat better than 3-to-1 as the analysis in Table II shows.

The average cost per day since April 22, 1927, has been approximately $3 for acid. The cost of handling has been much less as it requires only the time of two men for two periods of 20 min. each week.

The analysis of all water in this station is given in Table II before and after treatment.

Steam Plant Maintenance and Repair*

Questionnaires and data sheets were sent to the member companies operating steam plants. The following companies made partial or complete reports: The Hawaiian Electric Company, Ltd.—Arizona Power Company—San Joaquin Light & Power Corporation—Central Arizona Light & Power Company—The Southern California Edison Company—The Southern Sierras Power Company—Great Western Power Company—San Diego Consolidated Gas & Electric Company—Los Angeles Gas & Electric Corporation.

Boilers

The total boiler horsepower of the boilers reported is 116,450. These range in size from 250 to 2,545 hp. each. The steam pressures range from 175 lb. abs. to 400 lb. abs., and the steam temperatures from dry saturated (in some plants where no superheaters are installed) up to 700 deg. F., where they are installed. The average operating rating reported is 150 per cent. Several plants report as low as 75 per cent, and one reports an average rating of 300 per cent with 400 per cent as a maximum. All of the plants burn fuel oil or fuel oil and natural gas with one exception, and this plant (of the Central Arizona Light & Power Company) is using wet lamp black.

Five companies report that they operate boilers for a certain number of hours, after which the boilers

* Report of subcommittee of prime movers committee—R. F. Leefeld, chairman. G. K. Gordon, A. Y. Meudell, H. N. Mosher, C. W. Wiggins.

TABLE II—Analysis of water at Alameda Street station of Los Angeles Gas & Electric Corporation.

	PRIOR TO TREATMENT							AFTER TREATMENT		
	Raw City Water	Soft Water	Dist. Water No. 2 Evap.	Condensate Units 1-5-6	Pond Water	Feed Water No. Boiler Room	Water No. 42 Boiler	Pond Water	City Water No. 6 Meter	Water No. 30 Boiler
Sodium Hydroxide							31.82			37.16
Suspended Matter	None	None	None	None	Trace	None	Trace	Trace	Trace	
Silica	0.12	0.07	0.12	0.07	None	0.07	None	3.39	0.94	
Iron Oxide and Alumina	0.05	None	Trace	Trace	None	None	None	0.07	0.12	
Calcium Carbonate	9.94	Trace	0.21	Trace	0.12	Trace	Trace	14.41	9.35	
Calcium Sulphate	Trace	None	None	None	None	None	None	Trace	Trace	
Calcium Chloride	None	None	None	None	None	None	None	None	None	
Magnesium Carbonate	0.29	None	None	None	Trace	Trace	Trace	0.44	1.99	
Magnesium Sulphate	2.99	None	None	None	None	None	None	None	2.36	
Magnesium Chloride	None	None	None	None	None	None	None	None	None	
Sodium Carbonate	0.90	11.47	0.70	0.60	115.85	1.23	10.53	25.53	None	12.38
Sodium Sulphate	7.12	10.30	0.64	0.46	110.40	Trace	49.16	115.65	6.16	146.67
Sodium Chloride	2.89	3.18	0.38	0.38	72.95	0.48	30.77	34.63	3.18	
TOTAL	24.30	25.02	2.05	1.51	299.32	1.78	122.28	195.12	24.10	
Hydrogen Ion Concentration (pH)	7.9	7.8	6.8	7.7	8.5	8.5	8.5	Ratio: Carbonate to Sulphate, 1 : 4.53. Ratio: Carbonate-sulphate to hydroxides, 4.28.		

are taken off the line and given a general overhauling and cleaning. If any repairs are required during this period of operation the boiler is off the line only long enough to make the emergency repair. The Hawaiian Electric Company reports that they operate boilers four weeks and then take them off the line for a thorough cleaning and overhauling. This is the shortest period of operation reported. One company reports that their boilers are given a general overhauling once a year and repairs are made as soon as possible when needed. It has been the policy of the Los Angeles Gas & Electric Corporation that when boilers are taken off the line to make the necessary repairs, also to thoroughly overhaul and clean the boiler if a sufficient period of time permits. The Southern California Edison Company determines the overhauling period of boilers by the boiler performance data. These are based upon evaporating hours and relative gas and oil fuel hours.

It is generally agreed that it is easier on equipment to evaporate a given number of pounds of water in 1,000 hours than it is in 100 hours. It is much better to keep the boilers in service continuously than it is to cut them out during the light night loads.

Three companies are using chemical softeners, two others are using the lime soda process and two raw water. The Hawaiian Electric Company is using raw surface water, and the San Joaquin company is using deep-well water. Those using the Zeolite softened water turbine about once a year. Hawaii reports once a month turbining with surface water. One company turbines the tubes every 60 days using chemical treatment. The Central Arizona Power Company using the lime soda hot process treatment turbines the tubes once in 5½ years. The Seal Beach station of the Los Angeles Gas & Electric Corporation, using evaporated water from a deep well, turbines the three bottom rows of tubes about once a year, or after approximately 750,000,000 lb. of evaporation. Only two companies gave information comparing turbining of tubes to evaporation, so no basis of comparison of operation and water treatment can be given as was desired.

Very little trouble is caused by scale forming in the tubes. Only two companies report any scale. The Hawaiian Electric Company has a light, soft scale and the Central Arizona Power Company has a very small amount of hard scale. It is apparent, however, that the plants using water treatment suffer less from this trouble than those that do not.

Pitting of boilers is not causing any trouble as none of the companies has any difficulty in this respect. The Central Arizona Light & Power Company reports that it has an excessive blow-down. The Hawaiian Electric Company uses a device which eliminates blow-down. The majority of the companies have about one or two per cent of the total evaporation as the blow-down.

Insufficient data were received to give a very good idea of the life of boiler tubes. The Seal Beach station reports 0.00302 tube per 1,000,000 lb. evaporation, and the Alameda Street station 0.005 tube per 1,000,000 lb.; both are stations of the L. A. Gas & Electric Corporation. Several companies report that no tube replacements have been necessary.

The majority of the companies are using the same make of manhole gaskets. One company is using the same gasket several times but renews them yearly.

The Alameda Street station of the L. A. Gas & Electric Corporation, and the Southern California Edison Company are using de-aerators for the feed water to prevent pitting. (The reason for these installations is mainly for economizer protection.) What de-aeration is accomplished in the remainder of the stations is through the open heaters in addition to the main condensers. The two stations use chemical treatment to prevent pitting.

Most companies are using the same make of paint to prevent pitting. The San Joaquin Light & Power Corporation uses a mixture of kerosene and zinc above the water line and kerosene and graphite below the water line. Several of the companies are also using other brands. It seems to be the practice to paint the internal surface every time a boiler is down for cleaning and overhauling. As the companies have various periods for cleaning, no definite idea can be given of the life of any of these paints. One station reports that the paint is still good in one boiler after 750,000,000 lb. of evaporation.

Three companies use water to clean the fire side of tubes when down for overhauling. The remainder use air, steam, wire brushes and chains.

Deterioration of the fire side of tubes is prevented in the majority of the stations by keeping the boilers tight to prevent leakage. The San Joaquin Light & Power Corporation is using a mixture of graphite and cylinder oil at the tube-ends where they enter the drums. The Central Arizona Light & Power Company paints the mud drum with red lead. The San Diego Consolidated Gas & Electric Company uses a mixture of kerosene and graphite which is sprayed on the tube headers and hand-hole plates after cleaning periods.

The average time interval for making hydrostatic tests on boilers is approximately one year. Most of the companies, however, report that a hydrostatic test is made at any time that any boiler repairs demand it. Only one company reports a longer time interval for this test and that is once in two years. Only one company reports ascetylene welding of tubes for small holes. The remainder of the companies would renew any tubes which show any leaks which could not be stopped by re-rolling.

With the exception of three stations, all the boiler drums are outside caulked. These are comparatively new stations and no leaks have developed with the inside caulked drums of the boilers as yet. One company reports that to find a leak in the drum of an inside caulked boiler, they would drill and tap the butt strap for a ¼-in. fitting and apply air or water under pressure.

Superheaters

Superheaters are installed in all the stations of the companies which reported except one. The location of the superheaters in most boilers is the same, in the second pass between the first and second banks of tubes. One company is using a radiant type of superheater in conjunction with a connection type. The radiant superheater has two passes and is located in the rear of the furnace. A few leaks have developed in the connecting tubes and the elements exposed to fire have wasted away to some extent during one year of service.

The openings opposite the tube-ends are closed in the various plants with tapered fittings, tapered plugs with copper gaskets, and gaskets and plates. It seems that the rolled plug or taper fittings give the least trouble. The larger superheaters use plugs in the inlet ends of the tubes to get an even distribution of steam. One station found that it was necessary that these plugs be driven into the tubes a uniform depth in order that the quantity of steam passing through the drain hole in the bottom of the plug did not cause varying amounts of steam to enter the tubes. These drain holes are like a key-way and the steam is restricted only by the depth to which the plug is driven into the tubes. Care must be exercised in driving the plugs into the tubes as severe hammering will batter the ends of the plugs and restrict the openings.

No information was given relative to the life of superheaters except the statement by the Great Western Power Company. They have replaced all superheater tubes in ten years due to ends becoming brittle and wasting away.

Soot Blowers

Soot blowers are used by most of the steam plants in which superheaters are installed. The material of the elments depends upon the location within the boilers. The materials used are wrought steel alloy inclosed in cast iron tubes, Insuluminum calorized steel and Dialloy.

All of the stations have trouble with the element warping in the hottest pass of the boiler. The temperature of the gasses in the hottest pass is approximately 1,200 to 1,500 deg. F. at nominal ratings There seems to be a difference of opinion as to whether these elements oxidize, carbonize or are attacked by sulphur. It is necessary to replace an average of one element per boiler per year.

In most cases tubes are blown once a day. Where gas is used this is not necessary more than once in two days and seems to be regulated by a rise in flue gas temperature when other causes are eliminated. Tubes are blown in one large station every 16 fuel-oil hours and every 150 gas hours. Steam pressure at the soot blower nozzles is 140 lb. abs. Hand lances are used in the stations which do not

have soot blowers installed in the boilers. The nozzles in most cases are not cut very badly by the steam.

Air Preheaters

Air preheaters are installed in three plants. The San Diego Consolidated Gas & Electric Company have a revolving heat exchange element with forced and induced draft fans. The L. A. Gas & Electric Corporation installed tubular preheaters in the Seal Beach station. The Southern California Edison Company also uses preheaters.

The heat exchange surfaces of all these preheaters are cleaned with soot blowers. The Seal Beach station has had some trouble due to condensation of flue gases which formed an iron sulphate. The air passages of the preheater at Seal Beach have no way of being cleaned. As the Ljungstrum type preheater passes both air and flue gas, the soot blowers clean the entire element. It is unnecessary to by-pass the preheaters when firing up with either of these preheaters. The air passages of the tubular preheaters at Seal Beach show that oxidation is going on. No preventive has been used up to this time. The Southern California Edison Company reports no trouble with this equipment.

Breechings and Stacks

Steel and concrete stacks are used in connection with all the boilers. Three companies are using concrete stacks and one a steel stack lined with concrete. The breechings for all these stacks have been made by the builder of the boilers with two exceptions, the Hawaiian Electric Company made their own breeching and the Seal Beach station is using a standard make of breechings. No one is having any difficulty caused by expansion of breechings where they tie several boilers to one stack. All report the use of an expansion joint of some kind. All the stacks with one exception have the upper plate lap inside the one below it. This is the best in the opinion of all the operators.

The flue gas temperature from the boilers ranges from 240 deg. F. in those plants using preheaters to 650 deg. F. on boilers without either economizers or preheaters. The stacks are painted on an average of once a year. Three stations paint once in two years and one once in every six months. It is interesting to note that the stations painting once in two years are all using one make of paint.

Corrosion of the inner surface of the stacks is reported by all the steam plants using steel stacks. One company is required to renew the upper half of all stacks every 10 or 12 years. The Seal Beach station of the L. A. Gas & Electric Corporation is trying red lead and one of the heavy boiler seals with some success.

Economizers

Four steam plants are using economizers. One of the types of economizers has cast-iron tubes. Scrapers are used for cleaning which do not seem to cause any trouble due to sticking, providing they are worked regularly. No difficulty is encountered due to corrosion of tube surfaces on gas side. Tubes are not repaired, but renewed when required. No internal pitting is causing any trouble in this type of economizer. One statement is made that one tube is replaced per economizer per year.

The integral type economizers have caused considerable trouble due to tube-ends leaking at the top drum. This required excessive rolling which wore the tube thin at this point. This trouble was eliminated by making some changes in the delivery ends of the tubes to prevent the temperature changes causing stress at this point.

The steel tubes are subject to pitting when a very small amount of oxygen is present in the feed water. An effort is being made to keep the oxygen content below 0.2 c.c. per liter in order to prevent pitting. Small holes have been welded in these tubes, but replacements have been made recently. Nineteen tubes have been replaced since 12 economizers were installed in 1922 and 1923. These tubes are cleaned with soot blowers the same as installed in the boilers.

Boiler Setting

Cast iron doors placed in the setting are used in all cases for explosion doors. The same method of protection is used by almost all the companies in that they place loose fire brick back of the doors. No trouble is caused by these doors warping. It is a common practice to use some insulating material to prevent air leakage. Several methods are in use to determine air leaks in settings. The most used is the candle or open-flame lamp. Boilers enclosed in steel casings will give an indication of the location of leaks when the damper is closed causing smoke to be emitted from the joints.

Boiler seal and several high-temperature plastic cements are being used to stop leaks in brick work.

Burners

One make of steam atomizing burner of the inside mixture type is reported as being used by all of the companies using this type burner. The average life of the plates in the steam throat is about five months.

The outside mixture burners are all home-made. It is difficult to give any data on these burners further than to say that each user is satisfied and is having no trouble.

The mechanical atomized burners are in use in three stations. Burner tips which are supplied by the maker of the burners last about six months under continuous operation. Some special alloy tips have been tried out at the Seal Beach station, but owing to their short time of service, nothing definite can be said relative to their qualities. However, the indications are that the orifice will retain its original size for a longer time than the tips of stock material.

Most all companies report more or less trouble due to carbon deposits choking the burners. There is considerable difference of opinion as to whether this occurs under light or heavy load conditions. Two stations are using air to blow out the burners after they are shut off. This does not eliminate the daily cleaning, but it does keep burners in such a condition that they can be put back in service after being removed for several hours.

The Alameda Street station has found that a solution of hot water and cleaning compound cleans the burners very thoroughly. Further tests are to be made using this solution. It is necessary to remove all water from the burners which are not to be put in service at once as they will rust inside. The tips used in some of the stations are softer after a few weeks' use than originally. In some cases they are re-tempered.

The difficulties with the nuts which hold the tips in place seem to be general. In some cases they freeze to the burner barrel or else become so soft that it is impossible to bring them up tight enough to eliminate leakage without stripping the threads. Some are using a paste with success to overcome leakage, but others report that it is of no real value. The Southern California Edison Company is using nuts made of chrome-vanadium steel with considerable success. Stainless steel also is being tried by another company who will report later on the results.

Diffusers have caused some trouble. They apparently carbonize and must be renewed every few months. Several alloys have been tried, but the best seems to be a high-temperature alloy supplied by the maker of one of the mechanical burners.

Only one station reports trouble with ground joints. Seal Beach station had difficulty with the joint in the bronze head. It was finally decided to make a new coupling with a separate connection for each of the outlets. Prior to doing this there were times when the oil would by-pass the burner to some extent.

The relative capacity of burners has been determined in different ways. The most common is to keep all the orifices the same size by measurement. One company has used water which was weighed and the amount calculated to the equivalent in oil. Also they have placed pressure gages on each burner and with a fixed inlet and by-pass pressure have found some interesting facts. This matter of uniform tip capacities is of vital importance, and furnace economy largely depends upon uniform fires. It is almost impossible to regulate each burner to its proper adjustment.

Burners—Gas

Several stations reported using gas as fuel. Considerable trouble was encountered with those burners having an annular slot to admit the gas. The bowls would warp and crack causing gas to by-pass the burner and enter the furnace through the setting. This type of burner in the case of the Los Angeles Gas & Electric Corporation has been discarded and replaced with a

segmental burner with opening for gas admission through the inner perifery of the segments. This type of burner has proven very satisfactory. Very little information is given relative to gas burners other than the fact that most companies are using a burner of their own make.

Double Fronts

Heat to some extent causes these fronts to warp. The plants using air pre-heaters seem to have the most difficulty.

Where mechanical oil burners are installed using the air register, there is some air by-passing the registers due to the warping mentioned drawing the two parts of the burners apart. One station has placed sheet metal segments around the inner cone into which the register fits tightly.

Furnace Wall Peep Holes

A small opening in the brick-work with a cast-iron door is the most commonly used type of peep hole. Some have this opening covered with mica instead of the door. One station has tried three kinds of peep holes. They claim that the one with a wide angle and hinged door is the best. Peep holes using glass had two defects, glass would break and smoke up. The peep holes in the air-cooled furnace walls at the Seal Beach station originally were fitted with brick plugs. These plugs were easily broken and were replaced with stainless iron covers with small ventilating holes for protection against heat.

Forced and Induced Draft Fans

All of the maintenance and repairs to this equipment as reported by one of the two stations which have installed them is caused by the motor which drives them. One type of a.c. variable-speed motor gives considerable brush and commutator trouble.

Pop Safety Valves

As a whole the safety valves are causing but little trouble. The valves on the higher pressure boilers are steel bodied with monel metal trimmings and the lower pressures cast iron bodies with bronze trimmings. There seems to be about an equal number of inside and outside spring valves. Sagging springs cause but little difficulty. Several stations have had trouble due to steam by-passing between the seat and the body of the valve, and one has tried screwing the seat down into a paste of "smooth on," but had no success.

Several of the companies report that they pop the valves by hand daily; others weekly. Some report that about twice a year the pressure is raised on each boiler to test them under actual operating conditions. Seats and discs are subject to slight warping in rare cases and in one case steam leakage has occurred through the castings of a semi-steel-bodied valve.

All report that all adjustments can be made in a satisfactory manner. All boilers equipped with superheaters have the safety valve on the super-heater set from 4 to 16 lb. lower than the safety valves on the drums. One station reports operating a super-heater without safety pop valves. The method of maintenance of the valves is about equally divided. Some examine them just before the boiler comes off the line for repairs and repair only the defective ones, while others give all the valves a light grinding and thorough overhauling every time the boiler comes down.

Automatic Non-Return Valves

The automatic non-return valves, like the safety valves, use steel bodies and monel metal trimmings, and the lower pressures use cast iron and bronze. The majority of these valves are equipped with inside dashpots. However, there are a few equipped with outside dashpots. There are about an equal number of straight and angle valves in use.

Several reasons are given which cause the slight amount of sticking which is reported, growth of metal, dirty steam and lack of proper lubrication. In most cases these valves are depended upon when the boiler is given a hydrostatic test. Only one station reports using a blind flange which is inserted in the steam line to eliminate any possibility of leakage or trouble for the automatic valve. The general opinion is that it would not be good practice to use a gate valve on one side of the automatic valve subject to regular steam pressure and temperature due to the extreme temperature differential.

Steam-Header Gate Valves

Hand operated valves are used throughout all the stations with the exception of three. These stations are using power operated valves on the headers at the most important points. Two report that some difficulty had been caused by the limit switches, but by some minor changes this has been overcome.

Wire drawing causes but little trouble and is corrected when necessary by refacing the gate and seat in a lathe and shimming up the seat with a copper gasket. The growing of metal causes no trouble. Porous castings have been the source of considerable trouble to some of the companies. One company has had to weld several bodies of large valves. In most cases valves are operated only as required. Several companies state that they operate these valves weekly if they are not in daily use.

Of the smaller valves, those under two inches, both gate and globe valves are used, globe valves always being used where throttling is required. The bodies of these small valves in all cases are either forged or cast steel; for higher pressures they usually are forged. Both Monel and bronze trimmed valves are used. Screwed ends are preferred by plants using 300 lb. per sq. in. pressure and under, with but few exceptions. Higher pressures require the flanged type, preferably sargol welded.

The best combination of seat and disc is stated by five companies to be monel to monel. One has a preference for stainless steel to monel metal.

Piping

Three plants are using sargol welded joints for high pressures. They report that these joints are very satisfactory. Rolled flange bolts seem to be made of various grades and kinds of steel. Cold rolled round stock is the most used. Other steels reported are triplex steel, soft steel and chrome-vanadium. In most cases these bolts are turned from round stock threaded on both ends. The nuts for these flange bolts are also mostly cold-pressed steel and in some cases hardened. One company reports having had trouble with carbon steel bolts which became brittle and in some instances were found broken. These are being replaced with chrome-vanadium heat-treated steel, and nuts of cold-rolled bar stock.

Another company has had tensile strength tests made of bolts which were in service for varying periods of time. The strength of bolts in service for six months on a header carrying steam at 265 lb. abs. and 550 deg. F was reduced to 95 per cent of its original strength. Bolts in this same header for a period of five years show a strength of only 82 per cent of the original bolt strength. Bolts in a header supplying steam at 215 lb. abs. and 475 F after eight years tested about 80 per cent of their original strength.

Graphite and oil, or white lead and graphite is used as a lubricant when tightening bolts. Nuts seizing on the bolts after a period of time is reported by all the stations, making it necessary either to split the nuts or cut the bolt in order to break a joint. Nuts which are a loose fit are not generally desired due to the ease with which the threads are stripped. They are, however, less liable to seize.

The packing of valve stems when the value is open is not generally done. It is stated that in some cases with certain valves it is done. With the exception of a few stations, a sheet packing suitable for the most severe service is used for all purposes. Some stations use red rubber for cold water connections.

Boiler Blow-Down Valves

Two valves in tandem are used by all of the companies reporting except one. These valves are subject to pressures of 250 lb. abs. to 400 lb. abs. Seats and discs of the upsteam valves are made of various alloys: bronze, monel, steel and stainless steel. The life of the packing in these valves having a sliding sleeve, varies from 2,000 to 4,000 boiler operating hours.

In valves having aluminum parts, the aluminum seems to erode to some extent. The sliding sleeves are made of either monel or bronze. Some difficulty is reported due to scoring. The seat and disc life of the other types of blow-down valves is about two years.

Motors

Air-gap inspection of motors is made at periods from six months to a year. Some companies have no regular examination. It seems to be the practice to renew the

bearings when the gage cannot be inserted between the rotor and stator. The measurement allowed by two companies is from 0.010 to 0.020 in.

Oil Filters

Oil filters of both the gravity and centrifuge type are being used by the companies. Several stations are using the gravity-type filters in conjunction with the centrifuge type. The gravity-type filters in most cases are used on an overflow system, while the centrifuges used in conjunction with them are on the batch system.

The filter bags which are of a cotton and woolen mixture of cloth last about 4,500 hours in continuous service. All of the companies that use this type of filter purchase these bags for renewal from the maker of the filter with one exception. This company has them made locally. Most of the stations have a filter for each unit. Two report using a central filtering plant for the entire station and one has the filters to the units which have been installed in late years piped up to the oil systems of the older units so they can be transferred as desired.

These stations which report having a reserve oil batch and change from one to the other to allow time for settling are of the opinion that the extra cost is justified. One station is particularly of the opinion that the acidity does not build up as rapidly under this system as when the oil is used continuously. The amount of sediment removed from the bowl of a centrifuge is given as 16 oz. per 1,000 gal. of oil, is the statement of the Southern California Edison Company. The Hawaiian Electric Company finds only a thin coating on the centrifuge bowl after three months' operation with 10 bbl. of oil in the system.

Lubricating Oils for Turbo-Generators

The companies report using either an Eastern oil of paraffine base or a Western oil of asphalt base. The users of both these oils state that they are satisfactory. The viscosity of the Eastern oil averages 160; Western 145, both at 100 degree F. The acidity of both oils when new is practically O. Gravity A.P.I. Eastern 30 deg. and Western 23 deg., Eastern flash and fire points 417 deg. F and 462 deg. F; Western 330 deg. F and 360 deg. F. Demulsibility rate of the Eastern oil is 150 and the Western oil approximately 40.

Very few companies buy oil on specifications, or make any tests when received. One company reports making partial tests and another makes complete analysis of every barrel or batch of oil received. All companies report that the oil turns red after being in service. There are various opinions relative to the acidity allowable by those companies that make this check. One company allows an acid number of 0.5. This acid number is the milligrams of potassium hydroxide solution required to neutralize the acid of one gram of oil. It is probable that this figure is about correct, especially if the turbine in question is not operating regularly, as the acid will attack the bearings if it is much higher.

The average cleaning periods for the oil systems for the companies using Eastern oil is once a year, while two companies using Western state that the systems are cleaned every 90 days and another company using this oil on a stand-by plant cleans yearly. All companies with but one exception report that the sludge does form on the cooler tubes and in quiet places in the system. The coolers are cleaned in most cases with caustic soda, steam, or distillate. The reservoirs are cleaned by washing out with hot water, some using caustic. Sludge forms in the pipe lines of most units and is cleaned out at the same time as the rest of the system. No one reports any method of treating oil to prolong its useful life with the exception of filtering.

There is no definite information on when oil should be discarded. Some companies have not discarded any oil since it was placed in the unit. They add to the system as evaporation and other losses require. One company discards the oil if it gets very dark, or acidity runs above 0.5, or if oil is more than two years old. This company states that the evaporation is approximately 1 bbl. per 1,000 operating hours in a system containing 15 bbl. The Hawaiian Electric Company reports having run a 2,500 kw. unit six years on Eastern oil. During this period the oil was never changed or filtered, using only what make-up was required for evaporation. This system was found to be in as good condition at the end of the run as the systems that are now cleaned yearly. During this time there was no increase in bearing temperatures.

Lubrication of Ring and Wick Oiled Journals—In most cases the same oil is used for these journals as that used in the larger units. Some companies draw off the main units for this purpose and add the make-up to those systems from which drawn.

Oil For Reduction Gears—The oil used for reduction gears has a higher viscosity, averaging about 275 at 100 deg. F. Eastern and Western oils are used having a flash point of 350 deg. F. and fire point of 370 deg. F. No difficulty is encountered due to foaming. Oil is changed in this apparatus for the various plants annually, when overhauling is done.

Reduction Gears—The reduction gears in service all are hellical cut. Gear ratios range from 4 to 1 to approximately 10 to 1. No trouble is reported with this equipment such as working faces of gears pitting. Bearings have been rebabbitted when worn. This apparatus is, in most cases, inspected yearly.

Pump Data

The data relative to the most important pumps are from pumps in the following service: boiler feed, fuel oil to burners, condensate from condensers and condenser circulating water—66 pumps—all centrifugal with the exception of five plunger type pumps and one gear pump. Capacity: boiler feed pumps range in capacity from 3-in., 250 gal. per min. to 8-in., 1,800 gal. per min. The average temperature of the water to the pumps is about 200 deg. F. and maximum pressure of 450 lb. abs.

Condensate pumps range from 250 gal. per min. to 800 gal. per min. Most of these pumps are single-stage and either motor or turbine driven centrifugal type. The discharge pressure of these pumps ranges from 33 to 65 lb. abs. and the suction depends upon the vacuum maintained on the main condenser. The temperatures range from 60 to 100 deg. F. Fuel-oil pumps are of the gear and plunger types, operating under pressures from 60 lb. abs. to 365 lb. abs. The oil temperature is, in most cases, from 60 to 100 deg. F. The circulating pumps for condenser cooling water are the largest. The capacity range of these pumps is from 4,000 gal. per min. for 8-in. to 40,000 gal. per min. for 36 in. Some of these pumps, operating from cooling tower systems, operate against a discharge pressure as high as 55 lb. abs.

Steel shafts are used throughout. Some of these pumps have no sleeves on the shaft. Those that do generally use bronze, although in a few cases, stainless steel and chrome-vanadium is being used. The life of the sleeves ranges from 5,000 hours to an almost indefinite period, although the average life seems to be about 25,000 hours. There is almost the same number of these sleeves threaded on the inner and outer ends. Only one company reports having had trouble due to air leakage between the shaft and sleeve. This difficulty was remedied by countersinking the end of the sleeve next to the impeller and inserting a rubber gasket. This method has proved entirely satisfactory. The packing boxes and glands are all about the same size in proportion to the size of the various pumps. The glands in all are either cast iron or bronze and the glands and gland bolts are considered sufficiently strong. The gland bolts are made of either steel or bronze. The majority of the pumps are double suction with bronze impellers. Only two pumps are reported as having cast-iron impellers.

The packing mostly used is either flax or hemp impregnated with some lubricating material. One company is using metallic packing on two pumps. The life of packing is generally agreed to be about 5,000 hours. However, some stations report as high as 20,000 hours for a flax packing. No data were given relative to the metallic packing.

No trouble is reported due to throats eroding away. The life of the average impeller is, in most cases, not given, but it is evidently from one to ten years. This information is so incomplete that it cannot be applied relative to service and time. Suction rings also are of bronze with but few exceptions and in these they are cast iron. The plain type prevails as only a few pumps are listed as labyrinth type. No information given as to life of rings. The casings are in general cast iron. However, the higher pressure pumps have cast steel casings. The casings seem to be satisfactory with but one exception.

In condensate pumps, removing the condensate from

condenser wells, it is reported that the casings erode rather rapidly. The Southern Sierras Power Company reports that they have rebored the casings and inserted liners with satisfactory results. The cause of this erosion is not given by any who have experienced this trouble. Pumps of the type having rods and plungers are giving no trouble. Materials listed in the rods are given as brass and steel and the plungers as cast iron and bronze. The thrust bearings listed in the reports are marine, plain, and ball. Only a few pumps are equipped with a ball thrust bearing. Ring oiling is used on all the pumps. Only one company uses a heat exchanger for cooling the oil. No trouble of any kind is reported for these bearings.

The valves of plunger pumps for hot boiler feed water are listed as an asbestos compound by The Southern Sierras Power Company. The life of these valves is given as 20,000 hours of operation. Pumps of this type for fuel oil service are equipped with brass valves. The life of these valves is approximately 50,000 hours. No trouble is being experienced with these valves.

The couplings used between the centrifugal pump and the motor or turbine driving them are in most cases rubber bushed. The life of the bushings seems to be about 20,000 hours, although some couplings have been operated three times as long as this and are in good condition. The other couplings being used are jaw-and-leather link. No trouble is being encountered with these couplings.

Turbo Generators

The companies reporting on steam turbo-generators are: Southern Sierras Power Company; the San Diego Consolidated Gas & Electric Company; the Hawaiian Electric Company; the Arizona Power Company and the Los Angeles Gas & Electric Corporation.

The turbines in operation by these companies are as follows: Southern Sierras: 1 3,000-kw., 80 per cent power factor and 1 5,000-kw., 80 per cent factor. San Diego Cons.: 2 15,000-kw., 80 per cent power factor and 1 6,000-kw., 80 per cent power factor. Hawaiian Elec.: 3 10,000-kw., 80 per cent power factor and 1 2,000-kw., 80 per cent power factor. Arizona Power Co.: 1 2,500-kw., 80 per cent power factor and 1 6,000-kw., 80 per cent power factor. L.A.G. & E. Corp.: 1 3,600-kw., 1 5,000-kw., and 1 31,250-kw., all 80 per cent power factor, and 3 17,500-kw., and 1 10,000-kw., all 80 per cent power factor.

About half of the machines have the exciter direct connected to the main generator. One unit has a house generator direct connected to the main generator.

Thrust Bearings

Some of the smaller units listed as installed prior to 1914 have marine-type thrust bearings with from 12 to 19 collars. All of these bearings have bronze faces. The large and more recent units of this make have Kingsbury thrust bearings with babbit wearing faces. No one reports any wear on these bearings. All of these bearings have external lateral adjustment. No troubles of any kind are reported.

Other machines are reported as using a marine-type thrust bearing with bronze wearing faces in the smaller units and a Kingsbury thrust bearing on the larger units.

The third class of units are all using a marine-type thrust bearing with babbitt faces. The composition of this babbitt is not known by the companies operating the units. These bearings have either 8 or 9 collars on the units reported. There is internal adjustment, using shims. No difficulty is reported with these bearings. The wear as reported by the Los Angeles Gas & Electric Corporation is approximately 0.001 in. per 6,000 hours operation on this type of bearing.

Inspection

Most of the companies report opening the machines once every year for inspection and necessary repairs. Emergency governors are tested weekly by several companies, others test every shut-down and some twice yearly. The over-speed trip is set on all the units to work at from 8 to 10 per cent over-speed. The throttle is tripped in most cases at every shut-down. One company is making these tests weekly.

Couplings

The Hawaiian Electric Company reports that the couplings on the units have bolted sleeve pin-type couplings. This is the same type of coupling on the smaller units of the Los Angeles Gas and Electric Corporation. The large unit (31,250 kw.) at Seal Beach uses a "double" coupling. No trouble is reported due to any of these couplings.

One manufacturer's units have a plain jaw coupling. Another's units are equipped with jaw couplings with bronze inserts. The San Diego Consolidated Gas & Electric Company reports 0.010 in. wear per 10,000 hours operation. They will install new bearing plates in the near future after five years of almost continuous operation.

Bearings

All of the bearings are babbitted, self aligning and only one of the smallest unit has multiple sleeve. The largest journal reported is 16x24 in. and has a surface speed of 7,539.8 ft. per min. The highest surface speed recorded is on a certain unit. The speed is 8,482 and the journal size is 9x12 in. This machine is operating at 3,600 r.p.m. It is well to state here that most of the machines are operating at 1,800 r.p.m. which are being discussed in this report.

Bearings in most cases are fitted to journals. However, two companies report fitting to an oversize plug. Very little difficulty is encountered due to bearings scoring. Several companies report that bearings show spots which have been very hot. The temperature of the oil from bearings is rather uniform, the maximum reported being 160 deg. F., and the average 145 deg. F.

Blades

Information relative to the composition of blades is not given in general. Several of the units are reported as having bronze blades. The lashing wire has caused several companies some trouble. Blades seem to be more easily broken in the reaction turbines than in the impulse, although one company reports that they have had more trouble with the two stages of impulse blading in what is considered a reaction turbine than with all the reaction blades. This impulse blading is nickel steel. The blading of one of the larger reaction turbines has been, for the most part, changed to nickel. It has been found that double lashing wire is a great help.

Several operators of the impulse-type turbines find that blades do come loose at the roots in the intermediate sections. No remedy has been reported for this trouble, with the exception of trying blades of some other material.

Shaft Packing

One manufacturer's units have both impeller type water-sealed and labyrinth-type steam-sealed shaft packing. All of another manufacturer's units have impeller-type water-sealed glands. Various troubles are reported with both types, broken pins being the most common in the labyrinth steam-sealed type. The impeller of the water-sealed gland erodes. As this erosion goes on more and more sealing water is required. Two small units have carbon shaft packing, steam sealed. This type of packing is not causing any difficulty for these units.

Spares in Stock

The Hawaiian Electric Company carries the following spare parts in stock: oversize plugs for fitting bearings; one complete ring for impulse blades for both cylinder and spindle; one set knife edges for governor; one set of blocks and one spindle gear for same; one full set of blading tools. The Southern Sierras Power Company carries: 20 per cent of stator coils; one bearing, three sections cylinder blades for intermediate section and two intermediate sections for the spindle and one set of blading tools.

The San Diego Consolidated Gas & Electric Company carries the following stock: one set collector rings for machine field; one thrust bearing for each unit; one section of first intermediate cylinder blading; one set of steam nozzle sections for each unit; one set of knife edges for the governor; one set of blocks for each unit; one set of Gimball bearings for the units; one spindle for each unit; also complete set of oil pump gears for each unit is carried in stock.

The Arizona Power Company carries all four journals for one unit and three for the other; one thrust bearing; governor parts for each machine; one set of knife edges; one set of blocks; Gimball bearings; springs and spindles and three steam valves and cages for the governor of the larger unit; blading tools for the larger unit and carbon shaft packing and oil pump gears for both units.

The Los Angeles Gas & Electric Corporation carries the following parts in stock: oversize plugs for all turbine journals; one set of thrust bearings for the three 17,500-kw. units and one set for the 10,000-kw. unit; one set of first stage nozzles; one set of first stage intermediate segments with buckets and covers for the 17,500-kw. units and one set first stage intermediate segments with buckets and covers for the 10,000-kw. unit; one Gimball bearing; one set of blocks; one set of gears for the oil pump. For the 31,250-kw. turbine the following spare parts are carried: oversize plugs for the main bearings; knife edges and blocks for the governor and working parts of the main throttle valve, including seat and disc.

Underground Systems Committee Reports[2]

Indications are that underground construction gradually is receiving more and more attention among utility engineers in California. The distribution systems of the power companies in the congested districts of most of the larger Eastern cities are underground to a great extent and for this reason the personnel of the distribution departments in those companies includes many engineers who devote most of their time to this branch of the work. As a result of increasing interest and activity in underground construction and operation the past year witnessed greater co-operative effort and mutual exchange of ideas, as far as the underground systems committee is concerned, than heretofore has been experienced.

A special effort was made this year to appeal not only to the underground engineers, but also to those not intimately connected with underground work, by presenting a considerable number of relatively short papers on items of general interest and non-technical in character. It was the intention that such a plan would disseminate the largest amount of practical experience in the time available and best retain the interest of those in attendance, and in addition give a greater opportunity for discussion among the members. The real benefit derived by the engineers who attend the meetings results from the discussion of the papers and not from the mere reading of the papers themselves, papers which later will appear in the technical publications and can be read elsewhere by the individual. As in most other endeavors the man who devotes the most time and energy to the activities of the committee either by preparing and presenting a paper or by giving others the benefit of his experience through discussion, derives the greatest good.

The September meeting of the committee was devoted largely to a general discussion of the plan to be followed during the year and a brief outline of procedure by each member to whom a subject had been assigned. No reports were presented and to this extent the meeting was primarily an organization meeting. The subjects were divided almost equally among engineers in the vicinity of San Francisco and those near or in Los Angeles, and accordingly half of the papers were presented at the January meeting and the other half at Fresno, with but little duplication. Most of the reports presented at these two meetings are printed in detail on the following pages.

The January meeting opened with the presentation of a paper on "Electrolysis as it Affects Underground Lead-Covered Cables" and included a general discussion of the problem with a brief statement of the theory involved. A questionnaire brought replies which indicate how the various utilities handle the matter.

A number of Eastern utilities are going to voltages higher than 4 kv. for metropolitan underground distribution. One Western utility has been employing 11 kv. for this purpose for many years.

Another matter which has been the cause of a great deal of discussion at the Eastern technical meetings has to do with underground network systems which are intended to provide continuous uninterrupted service even in case of failure of cable or equipment. The star-star 4-kv. network is one type which probably is in greatest favor. A paper on the operation of a star-star underground system indicates that California has been operating such a system for as long as 30 years and that during that time most of the problems peculiar to such a system probably have been met and a solution reached satisfactory to the engineers concerned.

Bonding and grounding of underground systems and cables is covered in a resume of the manner in which this detail of underground construction is handled in the field. A paper dealing with single-conductor cables explains a number of points which have caused concern to engineers, particularly sheath currents in such cables.

The various utilities of the (San Francisco) "East Bay" cities for a number of years have handled the joint problem of electrolysis by a special joint committee, which is described in one of the following papers. It was thought that such a report would stimulate interest in other cities in this method of handling the problem in order that a better co-operation might exist between the utilities concerned.

The April meeting opened as a joint meeting with the accident prevention committee, a truly fine innovation and one which has large possibilities. A number of short papers on matters of interest to undreground engineers were included and are given on the following pages.

[2] **H. H. Buell,** Pacific Gas and Electric Company, chairman. **K. B. Ayres,** San Diego Consolidated Gas & Electric Company, vice-chairman. **Coast Valleys Gas & Electric Company:** T. W. Snell. **Glendale Public Service Department:** R. C. Smith. **Great Western Power Company:** G. H. Hagar. **Los Angeles Bureau Power and Light:** M. O. Bolser, C. H. Jenkins. **Los Angeles Gas and Electric Corporation:** C. B. Judson, E. R. Northmore, Z. T. Pettit. **Ontario Power Company:** C. W. Walker. **Pacific Gas and Electric Company:** R. E. Chapman, R. R. Cowles, G. L. Hill, H. G. Keesling, R. P. Lutzi, R. C. Powell, Paul Suransky, J. O. Tobey. **San Diego Consolidated Gas & Electric Company:** D. J. Kelly. **San Joaquin Light & Power Corporation:** H. H. Minor. **Southern California Edison Company:** F. M. Gallagher, N. B. Hinson, R. G. Sheppard, E. R. Stauffacher. **The Southern Sierras Power Company:** A. C. Putnam. **Standard Underground Cable Company:** Vinton Smith. **Westinghouse Electric & Manufacturing Company:** P. B. Garrett.

Cable Terminal Improvement

By C. H. Jenkins*

Various methods of terminating cables on poles are in use. It is desirable that the arrangement be inex-

* Report presented to underground systems committee.

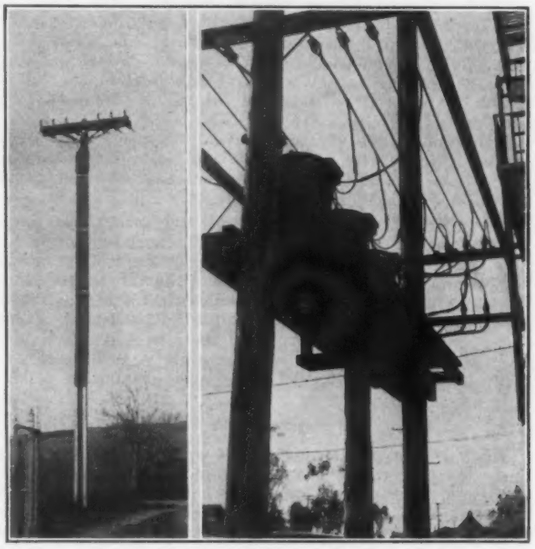


Fig. 1. General arrangements for mounting single-conductor, 220-volt cable potheads (left) and a typical example where such construction is used (right).

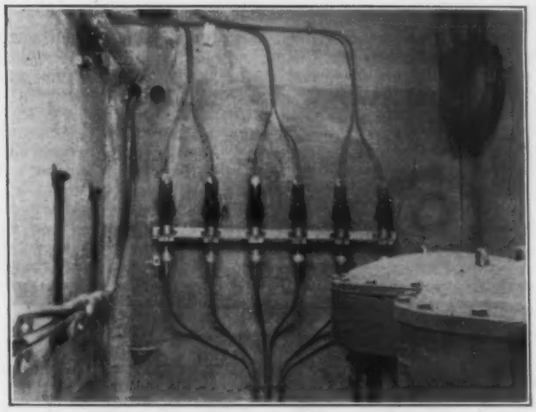


Fig. 2. A vault installation of single-conductor, disconnecting type potheads on secondaries of street-lighting transformers.

pensive, practical and durable, and yet present a satisfactory appearance. No radical change has been made recently by manufacturers in the general design of low-voltage cable terminals. Both the single-conductor and multi-conductor types are used by Pacific Coast companies.

Low Voltage.

Fig. 1 shows the general arrangement for mounting single-conductor 220-volt service cable potheads on a transformer rack, and shows also a typical example of a primary cable riser with single-conductor potheads. Fig. 2 shows a vault layout single-conductor disconnecting-type waterproof pothead mountings on secondaries of constant-current street light transformers. Fig. 3 shows a combination cable-joint pothead used on two single-conductor cables. Fig. 4 is an illustration of a typical application of conduit fittings for cable terminals.

High Voltage

The terminating of high voltage cable on poles presents a more difficult problem. The usual practice is to terminate in single conductors, although multi-conductor potheads are in satisfactory use. Fig. 5 shows typical 15-kv. installations.

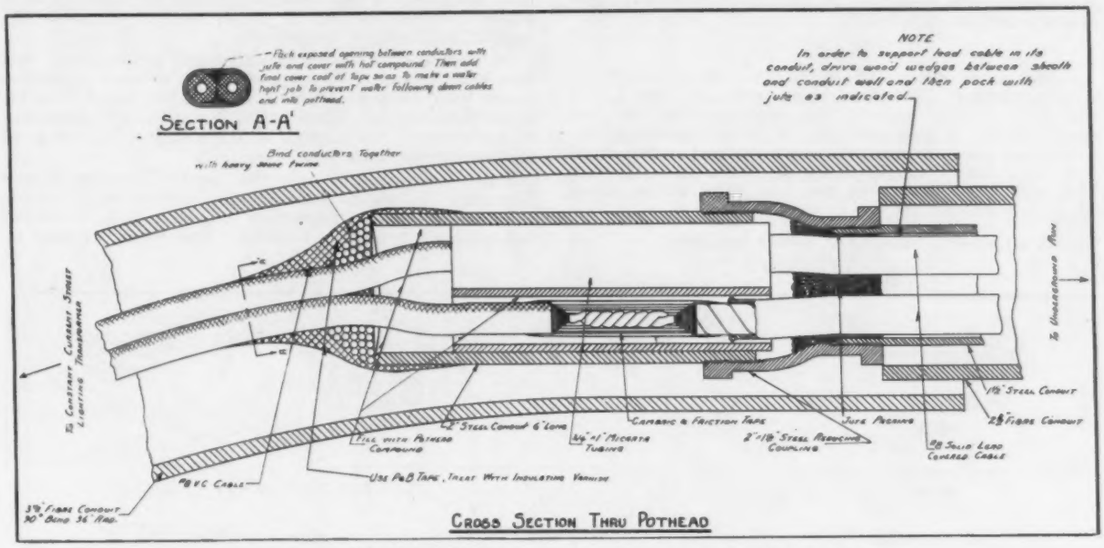

NOTE
In order to support lead cable in its conduit, drive wood wedges between sheath and conduit wall and then pack with jute as indicated.
Pack exposed opening between conductors with jute and cover with hot compound. Then add final cover coat of tape so as to make a water tight job to prevent water following down cables and into pothead.
SECTION A-A'
Bind conductors Together with heavy stout Twine
To Constant Current Street Lighting Transformers
To Underground Run
1½" Steel Conduit
1½" Fibre Conduit
2" Steel Conduit 6' Long
Fill with Pothead Compound
Cambric & Friction Tape
Jute Packing
2"-1½" Steel Reducing Coupling
#8 Solid Lead Covered Cable
#8 V.C. Cable
Use P&B Tape, Treat With Insulating Varnish
3½" Fibre Conduit 90° Bend 36" Rad.
CROSS SECTION THRU POTHEAD

Fig. 3. A combination cable-joint pothead used for two single-conductor cables.

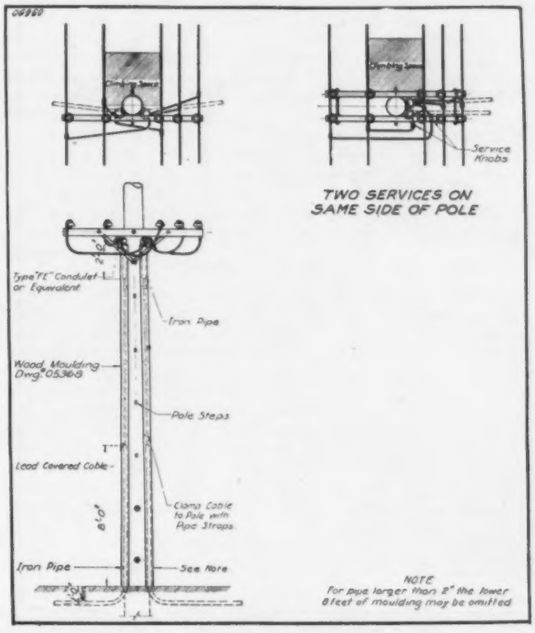


Fig. 4. A typical installation of conduit fittings for cable terminals.

Where oil-filled cable terminals with reservoirs are necessary to insure continued saturation of the cable insulation, the problem of preventing oil leaks in the pothead has been quite serious. Oil leaks occur through

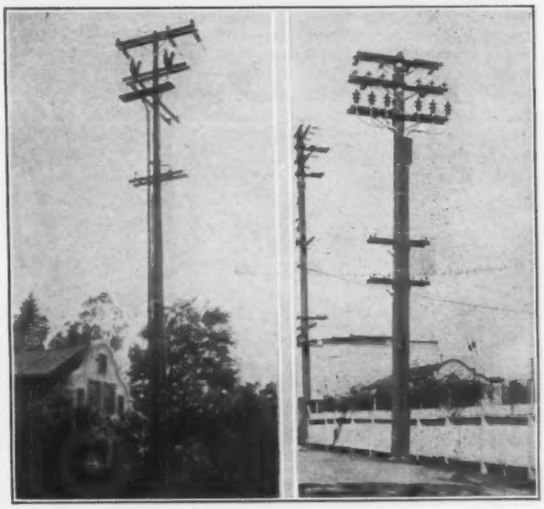


Fig. 5. Typical 15-kv. installations.

the cement between the porcelain and the metal base, and also in the screw joints when used.

It is expected that this difficulty may be overcome by metalizing the edge of the porcelain and making a wiped joint between the porcelain and the metal base or lead sheath of the cable.

Cable terminals for 132-kv. cable now are in use. They are similar in design to an oil-filled transformer bushing and are fitted with a base adapted for wiping to cable sheath.

An 11-kv. Underground Distribution System

By E. M. Beal and G. H. Hagar*

The San Francisco underground primary system of the Great Western Power Company operates at 11-kv., grounded. As started in 1909, it consisted of a number of single-phase feeders from the various substations and one three-phase emergency or operating feeder to which any single-phase feeder or portion of single-phase feeder could be connected. Later, three-phase feeders were run from the stations to carry single-phase taps, or single or three-phase transformer banks. All feeders are regulated at the stations with single-phase induction regulators.

Cables

Cables used are rated at 15 kv., either single or three-conductor. Standard sizes used are No. 2, 1/0 and 4/0. While formerly the company had its own specifications, it now uses the N.E.L.A. specifications. A weather-proof neutral always is carried in the same duct with every single-phase or three-phase feeder. This makes it possible to use iron pipe where street conditions necessitate.

* Report presented to underground systems committee.

Transformers

Transformers for single and three-phase loads are standard underground type, rated 6,400/120-240 volts, without percentage taps, each connected between one hot leg and neutral. Those for two-phase loads are one of the above with one transformer of 11,000/120-240-volt rating, without percentage taps. In this combination the 11-kv. transformer is connected across the two hot legs and the 6.4 kv. transformer is connected between the third hot leg and the neutral. Two 11-kv. transformers connected open delta also are used where it is necessary to serve a large single-phase load in conjunction with a small three-phase load on one set of secondaries. No percentage taps are used on these transformers because the feeders are relatively short compared to their voltage and are regulated.

Fuses and Switches

Fuses and switches used are all single pole. No three-pole switches are in service although they are being investigated. Fig. 1 shows the details of the oil-filled switch or fuse which has been in use for a great many years. It serves as either an oil fuse or a manually operated oil switch according to whether a fuse wire is inserted into the holder or whether it is solidly coppered. "21-C" oil is used as it is transparent, facilitating inspection.

On test at an Eastern manufacturer's laboratory this fuse interrupted 2,500 amp. at 11 kv. several successive times without any trouble. It "walked around" a bit when interrupting 3,500 amp., but was not damaged. It interrupted 6,500 amp. at 11 kv., but in doing so blew the cover off.

About three years ago the Great Western Power Company decided to redesign this switch with a view of increasing the rupturing capacity. A so-called "diving-bell" type was evolved. The cover, as may be

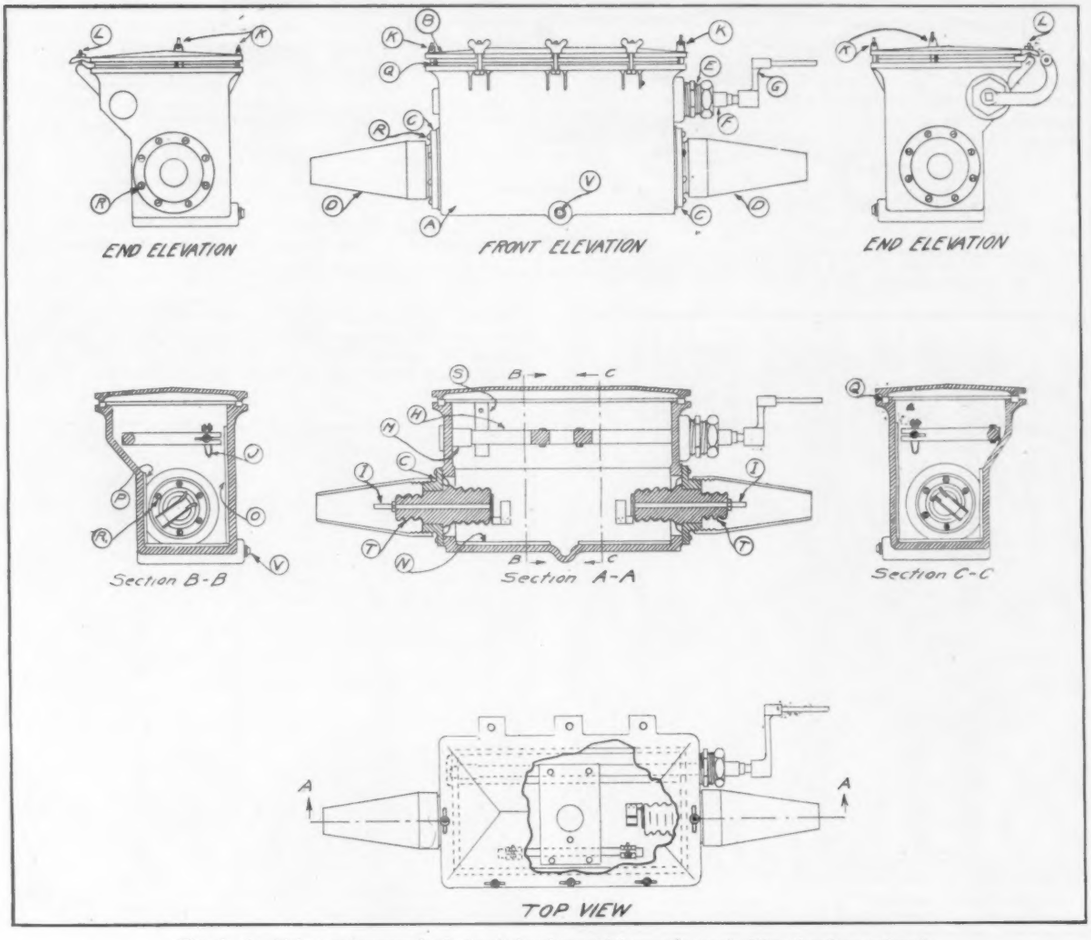


Fig. 1. An 11-kv. underground oil circuit breaker which may be used either fused or unfused.

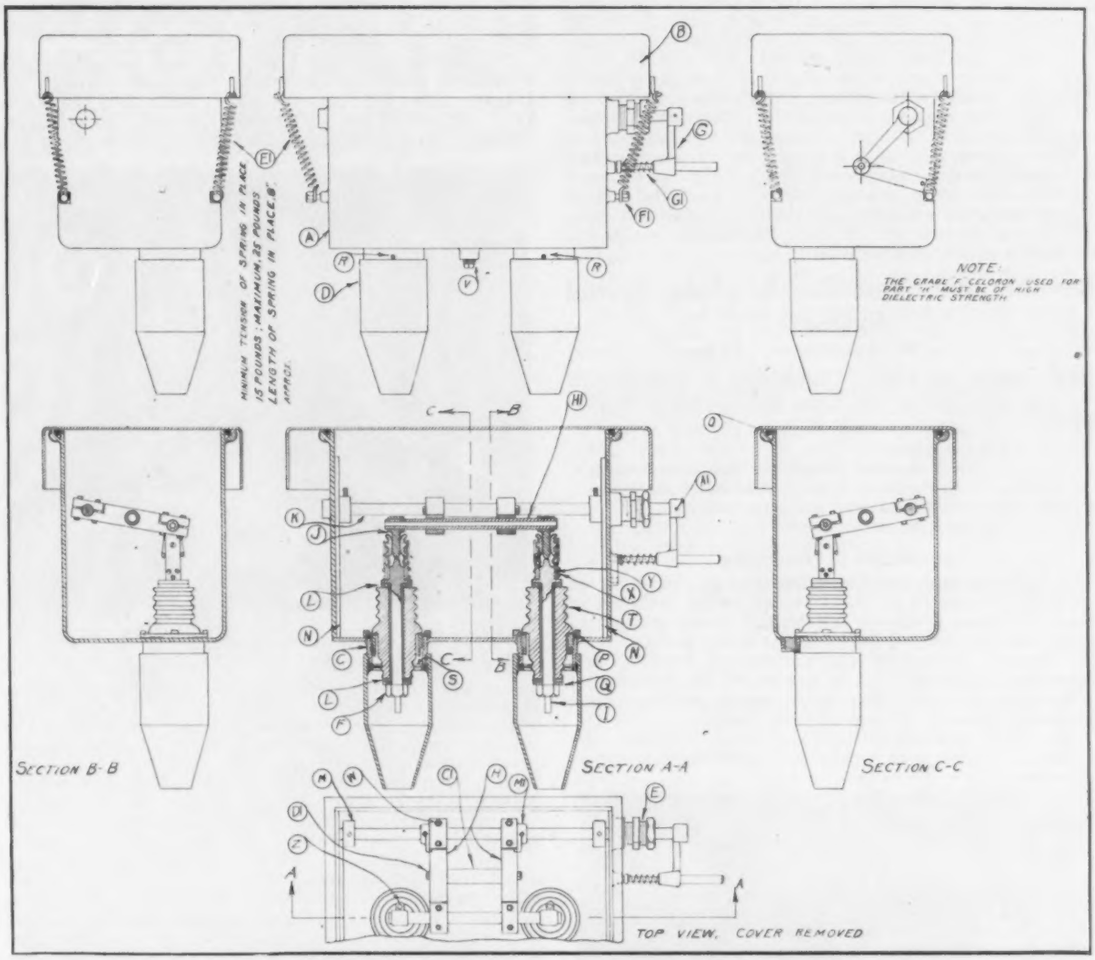

NOTE:
THE GRADE 'C' CELORON USED FOR PART 'H' MUST BE OF HIGH DIELECTRIC STRENGTH
SECTION B-B
SECTION A-A
SECTION C-C
TOP VIEW, COVER REMOVED

Fig. 2. Another 11-kv. underground oil circuit breaker which may be used either fused or unfused.

seen in Fig. 2, is larger than the box itself and extends down some 4 in. below the upper edge of the box. This entraps air when the manhole is flooded. The respective volumes are so proportioned that with the oil 1 in. from the top of the box the fuse will stand a 20-ft. head of water before any water will enter the box.

Bushings are brought out the bottom instead of the ends to save space in the manhole and to increase clearances to ground.

About this same time one of the manufacturers came out with an oil fuse somewhat similar to our original one, but of a much heavier duty. They rate this fuse at 200 amp., 15 kv.

The company now uses the latter type for sectionalizing any heavy fusing and its own for lighter fusing purposes.

Junction Boxes

No equivalent for the junction box which is common practice in 2.3 or 4-kv. primary systems is used on the Great Western system. When a transformer or a single-phase tap is connected to a three-phase cable it is necessary to make a multiple splice. Also, there are three-pole oil switches in use on the system. Thus when a switch is installed in a three-phase cable it is necessary to make a multiple splice and to put in three single-pole switches. One manufacturer recently has brought out a 400-amp., 15-kv., three-pole switch, which is reported to be in use to some extent in the East. Several other manufacturers are working on such a switch.

Low Tension

The low-tension portion of the Great Western 11-kv. underground distribution system, from transformer to service, does not differ from common practice in 2.3 or 4-kv. systems. Thus no discussion is warranted.

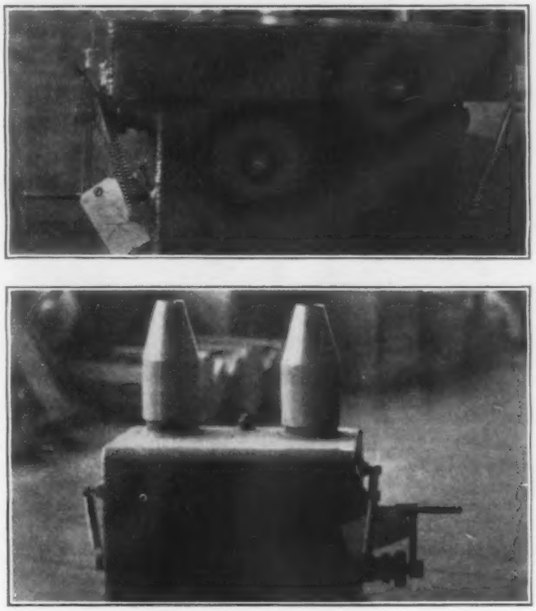


Fig. 3. (Above) View of an underground 11-kv. oil circuit breaker showing the cover, holding springs and operating handle. (Below) Bottom view of the same switch showing the wiping nipples and drain plug.

There is at present a need for a suitable three-pole oil switch and a junction box, or a substitute for the latter. These pieces of apparatus will have to possess the usual electrical characteristics for the 10-15-kv. class of voltages and in addition will have to be watertight and small in dimensions, as space in a manhole is at a premium and 38 or 40-in. clear diameter is about the practical limit of manhole castings and covers.

When these two problems are solved underground distribution with voltages of 10 or 15 kv. is no more difficult than with voltages under 5 kv. The higher voltage possesses marked advantages in voltage regulation and in amount of load which can be pushed through a given duct structure.

Bonding and Grounding in Underground Systems

By P. E. Chapman*

The subject, Bonding and Grounding of Underground Systems and Cables has been divided into five subtopics:

1. Details of Grounding.
2. Common Versus Insulated Primary and Secondary Neutrals.
3. Bonding Single-Conductor Cables to Prevent Sheath Currents.
4. Covering Cable Sheaths With Protective Coatings.
5. Use of Insulated Joints.

1—Details of Grounding

In underground duct installations the practice of bonding the sheaths of lead covered cables installed in these duct lines is almost universal. There appears to be no standard method followed, but many systems have like details. Primarily the purpose of bonding and grounding the lead sheath is to prevent the destruction of the cable armor by electrolysis and to provide a path for return current in case of cable failure.

The most common method of tying together the sheaths is by means of copper wire, or straps of copper,

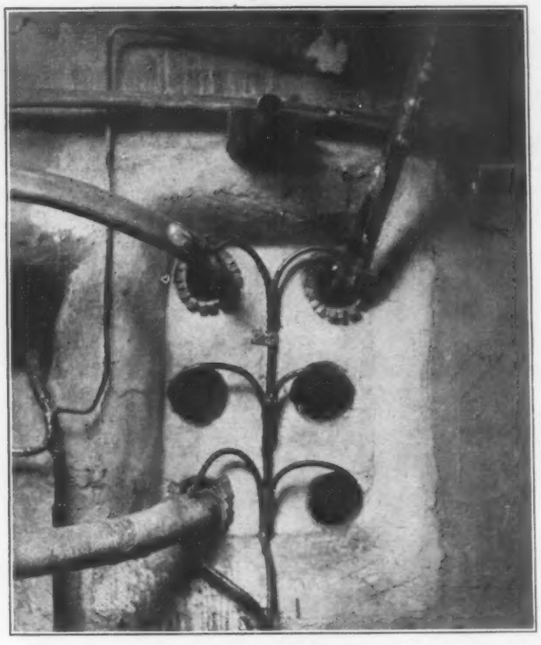


Fig. 1. A copper wire bond with taps brought out for future cables.

which are attached to the lead covering either by being wiped on with metal, or by means of straps of copper bolted around the lead sheath. Lead sheathing is used for bonding in some instances and it is claimed that the lead does not corrode as copper does. Obviously if lead is used the cross section of the bond or tie must be greater than that of copper if the same current carrying capacity is desired. Ordinarily copper wire of No. 4 B. & S. gage and larger is used and it usually is attached to the cables where they enter the duct line. This point of contact allows the smallest amount of material to be used and saves cluttering up the manhole with unnecessary wires and conductors.

To provide drainage points grounds sometimes are created in manholes by driving rods down through the bottom of the hole into the soil beneath, and the bonds from the cables are tied to this ground. In other instances connections are made between water pipes and

Fig. 2. A lead bonding strip.

the cables of other utilities so as to bring about the best possible results for all concerned.

In some localities there is a close tie between the utilities and a fine co-operative effort on their part to program the work of tying-in the grounded sheaths of their underground cables so as to produce the best results in the most economical manner. In the average underground distribution system the neutrals are well grounded at the substations and, as a rule, also on the consumer's premises. This arrangement gives a vast number of grounds in a system of any size, an arrangement which should allow the effective dissipation of any currents carried over the bond wire. No differentiation is made where cables of varying voltages appear in a manhole as regards the bonding of the sheaths of these cables. As a rule they are all tied together irrespective of the voltage of the cable.

In those instances where duct lines are constructed for housing high voltage cables only, the same practice is followed. All the sheaths of the cables are well bonded together and grounded in case there is a neutral wire passing through the duct run or, in many instances where tests have shown it advisable, their lead sheaths are tied directly to the return leads of the street railway system by the proper size bond wires. It is quite essential in any development of an underground system wherein the cables radiate from a center network and extend some distance into new territory that these cables be thoroughly bonded and grounded at the time of their installation. Otherwise serious injury may result.

2—Common vs. Insulated Primary and Secondary Neutrals

Common versus primary and secondary neutrals is a subject which has been receiving much attention. Due to the various methods followed by different companies no practice has been arrived at which could be termed standard. Secondary neutrals are grounded as a rule wherever possible, but primary neutrals are grounded in some instances at the station only although bare wire sometimes is used. There is a tendency toward the use of a common grounded neutral for both primary and secondary work, but it cannot be said that this is a standard practice as it is not followed out in all cases.

3—Bonding Single-Conductor Cables to Prevent Sheath Currents

Tests have shown that considerable sheath current is prevalent in single-conductor cables. As a rule not a great deal of attention is given to the prevention of such sheath current, but there is no question but that

* Report presented to underground systems committee.

a loss exists there which is preventable. Line groups of single-conductor lead-covered secondary cables should be drawn into one duct (together) where possible in order to reduce sheath current and voltage differences between them.

In transformer installations the cables emanating from the transformer should be parallel and bonded together. The use of insulated joints will prevent the flow of sheath current, but practically no insulated joints are found to be used for cables installed on transformers. There seems to be some hesitancy to install insulated joints on single-conductor cables and perhaps this is due to the lack of a proper joint that will keep out water. A good insulated joint must be designed to operate satisfactorily under water if it is to find a universal use.

The report "Operation of Single-Conductor Cables at 60 Cycles," by R. R. Cowles, which appears herewith also as part of the underground systems committee report, gives the values of induced voltages in sheath and armor of leaded cables.

4—Covering Cable Sheaths With Protective Coatings

The covering of the cable sheath with a protective coating is not universal although general practice appears to be to cover the lead armor with strip asbestos

Fig. 3. Cables covered with strip asbestos.

or a similar material wound on spirally and saturated with sodium silicate wherever such cables are exposed in manholes. For this purpose sheath asbestos approximately 1/16 in. thick sawed into strips is used. The finished job gives at least a ⅛-in. thickness of protective covering. The hardening of the sodium silicate gives a firmness which will take considerable punishment before the asbestos will fall from the cable.

Cement coverings have been used. There has been some agitation regarding damage done to lead sheath by the action of the cement. Although this subject has been a controversy for some time the use of cement still is followed in some localities.

In the present-day design of duct lines the method followed in bringing the duct line into the manhole so as to spread the ducts, leaving more space between them at their point of entrance, is commendable. Where cables are spaced with considerable distance between them there is a question as to wether or not the expense of covering the lead armor with a protective coat, such as niagrite or cement, is warranted.

In congested manholes having many low-voltage cables in close proximity to high-voltage cables all cables should be covered with niagrite or cement, or some similar covering, to give greatest possible protection.

5—Use of Insulated Joints

The use of insulated joints for other than transformer installations as mentioned under "3" is found in street railway work. A failure on a 600-volt d.c. railway cable where the failure is removed some distance from the substation will tend to return partly over the sheath of the cable as it usually is grounded or bonded according to common practice. To obviate any damage to cable of this kind it is advisable to use insulated joints, provided the cable is not submerged or liable to be submerged under water.

In the Twin Peaks municipal street railway tunnel in San Francisco a failure occurred on the lead cables which are used to furnish power. The resulting return current over the cables was so great as to melt the lead sheath in a number of places, necessitating the withdrawal and replacement of a large amount of cable. When it was replaced, instead of using the ordinary lead joints, insulated joints were provided using varnished cambric tape and painted with a water proof insulating compound.

In the new Duboce tunnel (San Francisco), now under construction, rubber-insulated cable will be used without the usual lead sheath armor.

Electrolysis of Underground Lead-Covered Cables

By Paul Suransky*

This report is to cover a study of electrolytic conditions affecting the underground structures and cables of member companies of the P.C.E.A., the determination of the causes, the remedies and various types of surveys used by the various member companies, and to determine whether or not electrolysis is a serious problem in this territory.

It is believed that sufficient attention has not been nor is being given to this problem.

The first part of this report will deal with the theory of electrolysis, its causes, standard methods for its mitigation, etc. The second part will deal with the conditions as found to exist on the systems of the member companies of the P.C.E.A., the remedies used by these companies, etc. This second part is based upon questionnaires which were sent out and from which conclusions have been drawn.

Theory of Electrolysis

Electrolysis is the process whereby an electric current passing from an electrode to electrolyte or vice versa causes chemical changes to take place in the electrolyte. Electrolysis also includes any chemical changes at the surface of an electrode resulting from the chemical changes in the electrolyte. Electrolysis is independent of the heating effect of the electric current. As used in this report "electrolysis" embraces the entire process of accelerated corrosion of underground metallic structures due to stray current. In the electrolysis of cable sheaths and other underground metallic structures and the rails of electric railways, the moisture of the soil with its dissolved acids and salts is the electrolyte and the metal pipes, cables and rails are the electrodes.

The practical electrolysis problem is due to stray current from electric railways. Stray current is that current which has leaked from the return circuit of an electric railway system and which flows through the earth and metallic structures embedded therein. These currents straying to earth from the electric railway tracks find their ways to water and gas pipes, power and telephone cables and other underground structures. When this current in turn leaves these structures corrosion occurs.

Stray currents are due to insufficient rail weights, imperfectly bonded track joints, poor road bed, infrequent cross bonds, insufficient conductance in the negative return, improper use of such conductance, excessive feeding distances, etc. The stray current leaving the rails will divide between the various possible paths offered and the amount flowing along any of these paths will be inversely proportional to the resistance of that path.

* Report presented to underground systems committee.

It will be found upon investigation that the stray current will leave the rails at points remote from the station and there pass through earth to the various underground structures and cables, thence along these structures and cables to leave them near the station and return through the earth to the rails and thence to the station. It will be found in the region where cables, etc., are near the station that these cables are positive to the earth and that where the current leaves the cable sheaths to return to the rails is "the" region where damage by electrolysis will occur. This area is called the danger area and will extend from 30 to 40 per cent of the distance from the supply station to the end of the line.

It may be noted that each ampere of current flowing steadily for one year will carry into solution about 74 lb. of lead or about 20 lb. of iron. The high electro-equivalent of lead and the thin walls ordinarily used for cable sheaths therefore require that unusual care be exercised in their protection.

In addition to the corrosive effect of the stray current upon the cable sheath it has been found by previous experience that the stray current in the sheaths causes a heating effect which reduces the current-carrying capacity of the cable. In some cases this condition may be found to be very objectionable. To give some idea of this effect it may be noted that single-conductor, 250,000-circ.mil cable of ⅛-in. lead sheath and paper insulation and with a normal current capacity of 335 amp. wil lhave its capacity cut to 261 amp. (22 per cent) by a sheath current.

As loads on congested underground systems continue to grow larger it is very essential that the carrying capacity of a cable be retained. Since stray currents decrease the carrying capacity of cables it becomes necessary to provide or devise some means for either entirely eliminating the stray current from the lead sheath of a cable or reducing the amount of these currents to such small amounts that the corrosive effect on and the amount of current flowing in the sheath may be neglected.

It is practically impossible to eliminate entirely the stray currents unless a double trolley system is used. The tendency in past and present practice is not to attempt to eliminate entirely such stray currents but to reduce them to such small values that no harmful effects will be produced by them.

Probably the first consideration to be given in order to accomplish this will be to make the resistance of the track or return circuit as low as possible. This may be done by seeing that rails of proper size are in place, that the bonding wire from one rail-length to the following rail is of proper size and is properly attached to the rails so that a minimum resistance exists, and that proper and a sufficient number of cross-bonds are installed in order to equalize the current flow between rails.

As it is rather expensive to change or replace the existing roadbed of a railway system in order to increase the resistance between the tracks and earth, not very much can be done by this means in order to cut down the amount of stray current.

One method of railway construction and operation employed to improve electrolysis conditions and one which is widely used is the "insulated negative feeder system." In this system instead of tying the tracks directly to the negative bus and depending upon the tracks and such other conductors as may be in parallel with them to return the current to the supply station, the connection at the station either is removed or a suitable resistance is inserted and insulated feeders are run from the station bus to various points on the track. By thus taking the current from the rails at numerous points high current densities and consequently high gradients and overall voltages are avoided and the amount of stray current decreased.

The various means as explained appear to be about the only practical ones for reducing stray currents other than the installation of additional substations, which for many other reasons is not feasible. If the stray current cannot be reduced to such values so as not to affect the corrosion of cable sheaths or underground structures, then means will have to be provided for draining the cable.

Electrical drainage consists in connecting the affected structure or cable to the railway return circuit by insulated conductors in such a manner that the stray current leaves the structure or cable through these connections instead of flowing to the earth. This prevents corrosion in the neighborhood of the drainage connections, but increases the current flowing on the structure or cable and the voltage drop in it which, of course, cuts down the current-carrying capacity of the cable. The latter may be taken care of by installing a low-resistance insulated, weather-proof, conductor in parallel with the cable sheath and to which it is bonded in manholes. Such an installation was described in a report submitted before this committee at the Fresno meeting in 1926.

Drainage connections usually are made by running copper cables either to the busbars of the railway supply station or to the negative return feeders. Connections to tracks are to be avoided because the failure of rail bonds might cause dangerous currents to flow over the drainage connection and also because of the possibility of getting a current reversal, particularly when the adjacent substation shuts down during the light-load period. However, when insulated negative feeders are used the drainage connections may be made to the rail terminals of the feeders.

Where drainage is used it should be reduced to a minimum consistent with the protection of the drained cable or structure in order to reduce the hazard to other adjacent underground systems. The drainage of one system tends to establish differences of potential between the various underground systems resulting in the interchange of current with consequent injury to the system at higher potential. In order to avoid this condition it is desirable to interconnect the various systems and drain them over common conductors. However, this latter method is not always possible for policy reasons.

It appears from the foregoing that more attention should be given to new underground systems. In laying new underground structures or replacing old ones it is in the interest of safety to locate them at as great a distance as possible from the rails. However, other conditions usually determine the location of such structures. Crossings under the rails should be avoided as much as possible and where they are made they should be made as deep as possible, but due to economy such depth probably will not exceed 4 or 5 ft.

It may be noted that cable sheaths cannot be considered as insulated from the earth even when installed in non-conducting duct material, but when compared to other underground structures such as pipes which are laid in the earth their resistance to ground generally is very high. The cable usually makes only a "line" contact with the duct walls while a pipe will make an entire surface contact with the earth. Therefore the matter of insulating cable sheaths from the earth resolves itself into providing proper conduit construction.

For power cables the conduit construction usually consists of a number of fiber or concrete ducts surrounded with an envelope of approximately 3-in. thickness and with about 1-in. separation between ducts. The effect of the various types of ducts on electrolysis probably will vary considerably, but this will be due mostly to the nature of the soil in which the ducts are located, the amount of moisture in the soil and the character of the paving over the ducts. In those locations where there is poor drainage the effect of moisture in the ducts would be to lower the resistance between cable sheath and earth.

Riser pipes containing cables naturally lower the resistance between the cable sheath and earth and thus permit the cables to pick up larger amounts of stray current than ordinarily would be picked up and thus in a way nullify the results obtained by good conduit construction. The matter of riser pipes probably should be given more consideration and investigation.

Various methods of construction have been tried out in order to prevent stray currents getting onto the cable sheaths. Some of these are discussed in the following paragraphs.

Waterproofing of underground conduits for excluding moisture and improving the conditions regarding electrolysis was tried out a number of years ago, but proved to be very expensive. Also it was found to be quite useless unless the manholes also were waterproofed, which did not appear to be practicable.

Another method tried was to enclose the lead cable in a covering treated with preservatives. This proved unsatisfactory and at times instead of acting as a protection it tended to accelerate electrolysis by localizing the corrosion.

Insulating joints have been tried as a means of electrolysis prevention, insulated joints being installed and

connection to ground plates being made under the floor of the manhole. If conditions were favorable for electrolytic action it was found that the plates acted as electrodes and were destroyed by electrolytic action. For this reason and further that insulated joints prohibited draining the cables, this practice has been abandoned generally.

In order to afford complete protection to cable systems it has been found that they should be interconnected and have drainage conductors of sufficient conductivity so located that the lead sheath of the cable network everywhere is lower in potential than the adjacent earth. Cable systems usually are installed in vitrified clay, creosoted wood, fiber or concrete ducts and if kept free from water the tendency to collect current is much less than if they were in direct contact with the earth. Owing to the higher resistance thus introduced between cables and the earth and the continuous character of the cable sheaths it usually is possible to lower the potential of the system below that of the adjacent earth in all localities by draining relatively small currents at one or more points.

In order to prevent the interchange of current through earth between the several cable sheaths in any conduit system it is necessary to bond the sheaths together at frequent intervals. Some companies make a practice of bonding at every manhole. Good practice requires such bonding at intervals not to exceed 500 ft. Bonding usually is accomplished by sweating a flat copper strip, a copper cable or a portion of lead cable sheath to all cables within the manhole. Where metal racks are used in manholes it is frequent practice to insulate the cables from such racks, this being done to prevent damage from electrolysis as well as damage in case of a burnout of one of the adjacent cables.

Questionnaire Results

In order to determine whether or not electrolysis is a serious problem in the P.C.E.A. territory a general questionnaire was prepared and sent out to twelve member companies:

1. Bureau of Power and Light of the City of Los Angeles.
2. Coast Valleys Gas & Electric Company.
3. Glendale Public Service Department.
4. Great Western Power Company.
5. Los Angeles Gas and Electric Corporation.
6. Ontario, Calif., Power Company.
7. Pacific Gas and Electric Company.
8. San Diego Consolidated Gas & Electric Company.
9. San Joaquin Light & Power Corporation.
10. Southern California Edison Company.
11. The Southern Sierras Power Company.
12. Western States Gas & Electric Company.

Electrolysis Questionnaire

I

(a) Has your company experienced any troubles or failures to equipment such as cables, conduits, pipes, transformers, etc., on your electrical underground system due to electrolysis?

Seven companies relied "yes."
Four companies replied "no."
One company has practically no underground electric system.

(b) State in general the extent of such troubles and failures.

Three companies reported few cases of cable failures.

One company reported considerable failures to 11-kv. and 4-kv. cables.

One company reported damage to water mains.

One company reported that the street railway negative return over the lead sheaths of the cables had resulted in no damage but in a high temperature of the cables.

One company reported that when it owned the underground system in a certain large city there was considerable trouble due to electrolysis. Most of this trouble was on telephone cables, which probably was due to the thin lead sheaths used.

One company reported condenser tube distintegration on turbines resulting from street railway negative return current.

II

(a) Does your company consider the electrolysis problem in your territory of sufficient importance to warrant investigation by the underground systems committee of the P.C.E.A.?

Six companies replied "yes," one of which modified its "yes" by, "do not consider it to be of major importance."
Five companies replied "no."

III

(a) Are there any joint committees for the mitigation of electrolysis in any part of your company's territory?

Three companies replied "yes."
Seven companies replied "no."

One company stated that there is no regularly organized joint committee on electrolysis, but there has been close co-operation between the several railway, cable, and pipe companies.

(b) Give a brief description of how the above committees function.

One company reported that the co-operative effort had been confined mainly toward securing restricted and avoiding competitive drainage.

Another company replied: "A committee of all interested companies with a field crew. Companies donate time of men for work on their own plant.

Another company replied that a general committee with representatives from all interested utilities and municipalities meets yearly and outlines the policy for the following year. The technical committee of five members meets monthly and carries on the work of testing, making reports to the general committee, etc.

(c) Have the above committees proved to be satisfactory in solving electrolysis problems in your territory?

Three companies replied "yes."

One company stated that conditions have been improved greatly since the committee has been functioning.

The company which replied that there is no regularly organized joint committee (as per question No. 3-a) reports that the present co-operation is fairly satisfactory but believes that a joint committee would give still better results.

IV

(a) When underground equipment fails on account of electrolysis does your company attempt to remove the source of the trouble or does it just replace the damaged equipment?

One company makes surveys to determine if possible the cause and proper mitigation of trouble.

Four companies attempt to remove the source of trouble or replace the damaged equipment, depending upon the extent of the trouble.

One company notifies the company responsible for the trouble.

Another company reports that where there is a joint committee the damaged equipment is replaced and it attempts, through the joint committee, to remove the source of trouble. In other parts of this company's system it determines the source of trouble by its own efforts and attempts to remove it.

V

(a) Does your company make electrolytic surveys on existing equipment?

Six companies replied "yes."
Four companies replied "no."
One company replied "very seldom."

(b) What type of surveys are made?

Voltmeter and ammeter surveys—two companies.
Voltage tests at irregular intervals—one company.
Voltage tests with milli-voltmeter—one company.
Potential difference among various structures, current flow in drains, soil corrosion, etc.—one company.

Spot readings only have been taken in the past, now getting some new equipment so as to be able to take continuous readings—one company.

(c) To what extent are such surveys made?

One company replies that it all depends upon circumstances.

Another company selects governing locations on system for tests. As a rule conditions have been good, yet as system enlarges in area and scope more difficulty will be encountered.

One company reports that its whole system in each of the underground territories has been gone over completely within the past year.

One company's cables parallel the telephone company's cables and all are bonded together so that it has made no tests, but interviews the telephone company's test men.

Another company states that where there is a joint committee, the committee has a crew of eight men constantly at work. In another part of its system it makes a survey over its entire underground system about once a year, while in other parts of its system it makes surveys only when the occasion for one arises.

VI

(a) Before building duct lines, does your company make electrolytic surveys to determine the existing electrolytic conditions?

Ten companies replied that no such surveys were made.

One company reported that it has not been making such a practice, but just had occasion to make one and recently completed it.

(b) Have such surveys, as mentioned in (a), proved to be of value in forecasting what the electrolytic effects will be on equipment to be installed in the future?

The one company which recently made such a survey reports that this work has not advanced far enough to determine its value as yet.

VII

(a) Name the various classes of underground equipment, such as cables, conduits, etc., in the order in which they have been affected by electrolysis on your company's system.

From the replies received, the order is:

1. Cables.
2. Conduits, iron.
3. Water and gas mains and services.
4. Condenser tubes of turbines.

VIII

(a) Please give your general views on the subject of electrolysis and any suggestions or comments you may care to make.

Following are the comments as received:

1. "It is our opinion that electrolysis is a live issue. Lead is not subject to much natural corrosion in the ground and should last almost indefinitely. The fact that there are failures and that old lead when pulled out frequently shows decay indicates electrolysis has been at work. If it were not for drainage bonds to overcome electrolysis, the loss would be heavy. These drainage bond connections in particular and electrolytic conditions in general should receive careful attention."

2. "It is believed that electrolysis is a local problem and can better be cared for by local committees than by a P.C.E.A. committee. The latter can be of service only in studying the methods to be used. This has been done to some extent."

3. "Electrolysis should be carefully watched."
4. "There is difficulty in effecting complete cure in many cases of trouble because of the cost of preventive means and the inability of the railway companies to meet such expense. Compromise is necessary in most cases; even so it is possible to greatly improve conditions in many instances."
5. "Think subject vital, as with expansion of cable systems and increase of long radial transmission cable lines the damaging effect of vagrant earth current will become more apparent."
6. "It is believed that less attention has been given to this subject and that less therefore is known about it than any other detail connected with underground work, although as regards failure of equipment it probably is next in importance to cable loading and temperature. I should like to see a comprehensive review of experience and methods in this connection in the entire country with recommendations as to the best solution of the problem."
7. "We think this subject is of enough general interest so that we will be glad to see the P.C.E.A. collect data from the whole state and make it available for individual power companies."

Conclusions

From the replies to the questionnaire it appears:

1. That the majority of the operating companies do have electrolysis troubles.
2. That where joint committees exist these committees function satisfactorily.
3. That no definite methods for the mitigation of electrolysis are used by all the companies.
4. With our underground systems daily growing larger and larger, with higher and higher voltages being used, with the necessity of keeping cables loaded to their maximum efficiency and with an ever increasing and incessant demand by the public for a continuous service entirely free from interruptions, it is essential that these cables be properly protected from damage from any outside source. The questionnaire indicates that underground cables are affected by electrolysis to a much greater extent than generally is realized and that electrolysis is a subject that is little understood by most of us. In other words electrolysis is a real problem in the P.C.E.A. territory. Such being the case a further study will be made of this subject, said study to deal with the technical and in order that this committee may arrive at recommendations as to the best solution of the problem.

Operation of a Star-Star Underground System

By J. O. Tobey*

Before taking up the main subject of this paper it is thought advisable to give in brief generalities the early history of the Sacramento 4-wire primary and secondary distribution which is ranked among the pioneers of its kind.

This system was adopted about 1895 as a convenient and comparatively inexpensive method of

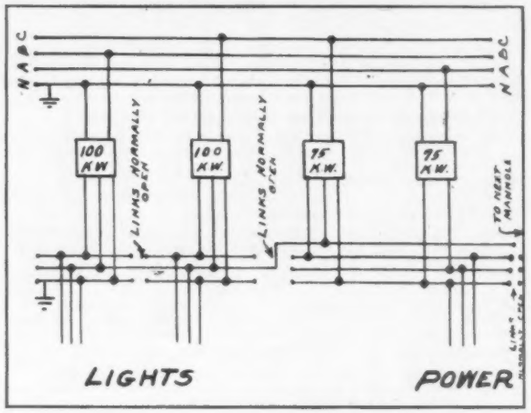


Fig. 1. San Jose system, star primary and delta secondary.

handling from one set of secondary mains both lighting and power consumers in the immediate vicinity of the one distribution station. The venture has proved so practical and satisfactory that it never has been changed.

During the summer of 1895 the Folsom power plant was constructed by the Folsom Water & Power Company. Its installed capacity was approximately 4,000 hp. in 3-phase generators and it supplied electrical energy to Sacramento 22 miles away, over 12 No. 1 copper wires at 11.2 kv. At the Sacramento substation this energy was stepped down to 500 volts to supply

* Report presented to underground systems committee.

the Southern Pacific shops and other consumers near the station. All consumers' motors were wound for 440 volts, which voltage is still standard in the Southern Pacific shops.

Outside of arcs practically no electric lighting and power had been distributed in Sacramento prior to this time and accordingly one of the first problems to be met was the development of a load and a distribution system to serve it. The most readily obtainable and accessible lighting load at the time was the business district of the city along J and K

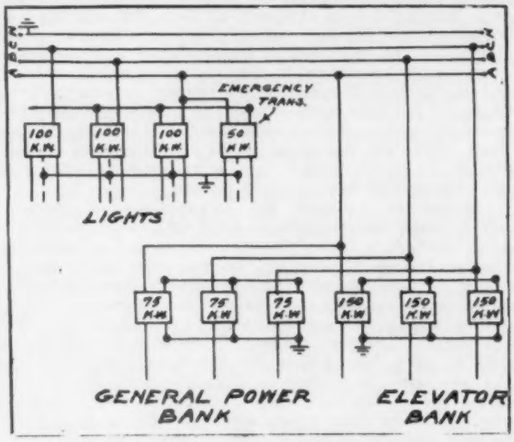


Fig. 2. San Francisco system, star primary and delta secondary.

Streets about 1,000 feet distant from the substation. To reach this, a 4-wire grounded-neutral secondary overhead network, with approximately 250 volts between mains and 144 volts to neutral, was extended. This voltage permitted appreciable line loss and still gave a good voltage for the lighting requirements, but single-phase hand-operated voltage regulators of pioneer vintage were installed to give better voltage regulation.

Pilot wires were strung back to the station from various load centers to indicate the lamp voltage at those points. The various feeder circuits were tied together at the consumers end and each phase of each circuit was provided with a single pole switch at the station. With this arrangement it soon became a unique operating procedure to give still further voltage regulation by varying the line loss through the opening or closing of one or more of the single phase switches at the station, the idea being to keep a balance between the copper and the load. By that time some of the consumers were located half a mile from the substation.

During this period service also was being supplied to the city's residential district through 1,000-volt circuits, transformation generally being to 104-208 volts delta.

As the load in the business district spread and increased beyond the capacity of the low-voltage station feeders, 1,000-volt primary circuits were run to the load centers and transformers of the 1,000-2,000/104-208-volt variety were installed with their secondaries star-connected. Later the primary voltage was increased to 2.4 kv. and in 1911 still further increased to 4.1 kv. by "starring." At that time both primary and secondary networks in the business section of the city, comprising some 30 square blocks, were placed underground and both the primary and the secondary neutrals were grounded.

Thus the star-connected network grew from nothing to the present load of some 3,200 kw. at 120-208 volts secondary potential.

During all this period it has been necessary to supply all types of service. Although this has required a constant observance of the voltage conditions by the sales department and a general education of contractors and dealers as to the voltage requirements of the various equipment installed, still the burden has not been great. Furthermore, the cash outlay of either company or consumers required by the conditions is of no consequence. To the contrary, savings to both have been effected.

Some difficulty was experienced with the 3-phase, 208-volt supply when one of the first a.c. elevators was installed. This was not serious, however, but to prevent further trouble the elevator people have been kept advised of the requirements and their motor operation has always been satifactory without any extra expense to their customers.

Some minor difficulties have been encountered where new buildings have been constructed in Sacramento and which were designed by outside engineers and architects not familiar with the Sacramento system, but these always have been very easily handled.

Heating equipment such as large electric ovens, grills, waffle irons, etc. which were wound for 220-volt service have given some trouble and in a few

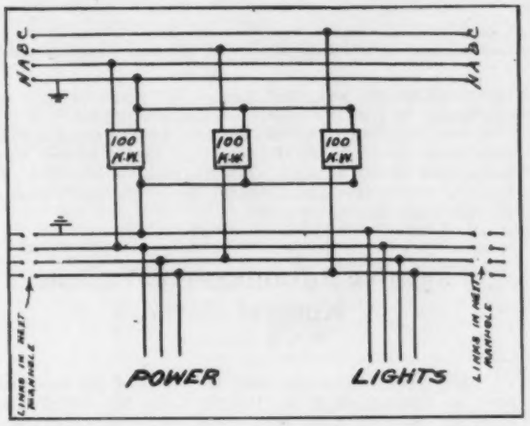


Fig. 3. Sacramento system, star primary and star secondary.

instances have necessitated a replacement of elements. No difficulty ever has been experienced, however, where these heating appliances were wound with 110-volt elements (these, if desired, to be cut in series for 220-volt operation) as the use of the 110-volt arrangement of the elements readily lends itself to the operation of the equipment either by a supply from a neutral and two mains or, if of large capacity, by a neutral and three mains. Either of these necessarily require polyphase metering, but this is not found to be a disadvantage although in some cases the meter costs may be a little higher.

For large electric ovens of say 15 kw. or more, the 110-volt element (if connected in three multiples and these "starred") gives a wonderful combination and permits a desirable load balance between phase conductors and transformers. It also permits high transformer load factors which in itself is of so much importance in underground systems where transformer space rapidly is becoming of grave importance. Other single-phase heating appliances together with single-phase or three-phase motors can be supplied readily from this same set of mains and the metering of such an installation is simplicity itself. For smaller installations only one polyphase meter is necessary and for larger installations three current coils with the meter will meet the requirements. Lighting also can be supplied through an installation of this kind if rate schedules permit.

Some complaints of low voltage have been experienced where the 208-volt three-phase service has been supplied to refrigerator or similar motors, but these invariably have been through the fact that relay settings for the overload protection of such motors have been made in the factory. After a small increase in relay setting was made no further complaints were registered. This may be argued by those opposed to the star system to be bad practice due to the possible overloading of the motor beyond its current rating. However, considering the fact that general practice permits full name-plate rating at a 20-per-cent variation in voltage, the matter seems not of serious importance.

One of the neatest installations is an apartment house in Sacramento where each apartment has 120-volt lighting, a 110-220-volt range and 10 kw. in 208-volt air heaters. The latter were specially wound for 208 volts which, of course, simplified the building wiring. Had they been wound for 110-220-volt service, the same as the range, a special winding would not have been required although a little additional building wiring expense would have been required through the necessity of a third wire for each heater. Each apartment is metered with one polyphase meter. Hot water for the building is supplied by a 15-kw. three-phase heater supplied at 120 volts per phase. The transformer load factor is ideal, considering the nature of the load, and in addition the load is nicely balanced between all three phases.

To permit heating equipment to be readily adaptable to the star connection without being wound for 208 volts, it seems that manufacturers would be justified in providing a line of equipment wound for multiples of 110 volts and so arranged as to permit operation on one phase at 110 volts; or on single-phase three-wire 110-220 volts; or on two phases of star supplied by two "hot legs" and a neutral, thus giving full voltage on a 110-220-volt connection; or on three phases by three "hot legs" and neutral. This would make a flexible scheme of winding, especially for the larger heating appliances, and would permit their use on either delta or star-connected secondaries without change other than terminal connections.

If correct engineering practice will not permit the 208-volt three-phase motor supply as a commercial consideration and if manufacturers cannot be prevailed upon to manufacture equipment that will meet the situation, then I still am in favor of the star system, even though it may be necessary to adopt the auto transformer method for boosting the phase voltage to meet name-plate ratings. Such a system is in successful operation elsewhere and if made a standard along with the secondary star network, I think a step would be made in the right direction.

Contractors in Sacramento are heartily in favor of the four-wire star system for building wiring and in numerous cases they have endeavored to "sell" the idea in other territories where it was not standard.

A marked difference in labor costs has been found in favor of the Sacramento star system, as compared with local outlying delta, open delta, and three-wire single-phase secondaries, due to the ease and simplicity of balancing phases and of keeping them balanced. This is particularly apparent when recognition is given to the fact that in the latter we are forever worrying about the possible and probable change of balance between the outside legs of the single-phase three-wire secondary which may result in a serious overload on

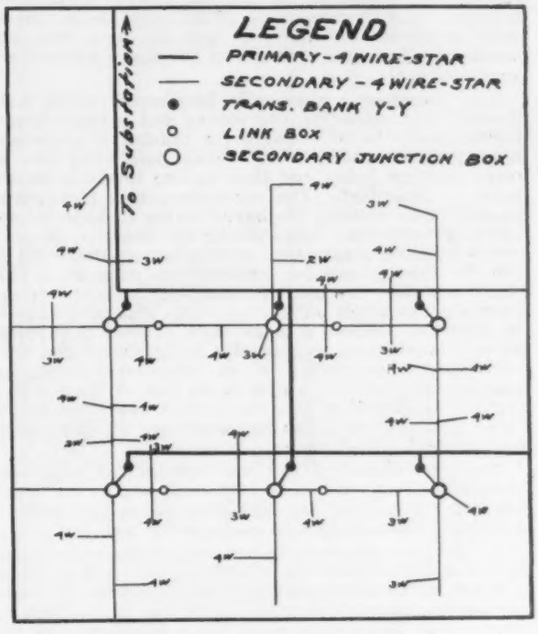


Fig. 4. Typical section of Sacramento underground network.

half of a transformer winding. This, of course, never results with the star secondaries as the entire transformer winding is in use and only phase balance has to be reckoned with.

TABLE I—Comparative data between Star and Delta-connected secondaries on 4-kv. star feeders in underground systems.

Feeder Data	Sacramento Star Secondary		San Jose Delta Secondary		San Francisco Delta Secondary
	A-2	A-3	A-500	A-900	C-5
1. Nominal rating	1,500 kva.	1,500 kva.			2,500 kva.
2. Primary voltage (regulated)	4,255–4,404	4,255–4,404	4,070–4,255	4,075–4,220	4,083–4,325
3. Peak amperes	170	171	198	172	170
4. Peak kva.	1,283	1,292	1,458	1,259	1,275
5. Kw. hr. for a 24-hr. period	15,360	15,440	14,650**	13,100**	12,420
6. Avg. kw. for a 24-hr. period	640	650	610	546	518
7. Total kva. of distribution transformers	1,590	1,695	2,381	2,181	1,815
8. Kw. hr. for full load on trans. for 24 hr.	38,160	40,680	57,200	52,400	43,560
9. Peak kva. load to kva. trans. capacity	81.0%	77.0%	61.2%	57.7%	70%
10. Avg. kw. load to kva. trans. capacity	40.0%	38.4%	25.6%	25.0%	28%
11. 24-hr. load-factor on feeder*	49.8%	50.0%	41.8%	43.4%	40%
12. Trans. cost per kva. of feeder peak	$10.15	$10.09	$11.12	$11.69	$9.17
13. Maximum difference in phase balance	15 Amp.	10 Amp.	80 Amp.	110 Amp.	20 Amp.

*Note: Power factor disregarded in computation of No. 11.
**Calculated by using average current for 24 hr. and 85 per cent power factor.

It is a possibility and even a probability that in the future distribution transformer loading will be determined by oil temperature rather than by other means. Therefore, the problem becomes one of protecting the 110-220-volt transformer from injury due to an overloaded half of its winding without excessive oil temperature being shown. It is safe to say that the expense of keeping a proper balance between sides of a transformer supplying a three-wire secondary and at the same time keeping a high load factor on the transformer without taking chances on its injury is something every operating man would like to be relieved of.

Through information obtained from the distribution department of the Pacific Gas and Electric Company at San Jose and San Francisco information has been obtained which is shown in the accompanying table. Even though the Sacramento tabulations are not entirely complete, due to certain variables, the data still are sufficiently accurate to make a good showing in favor of four-wire secondaries. Comparisons shown by items 9, 10, 12 and 13 all are favorable to Sacramento insofar as transformer loading, phase balance, transformer cost, etc., are concerned, with the exception of San Francisco transformer cost which is lower because the average size of transformers is greater reflecting the smaller cost per kva. of the larger transformers.

Transformer connections are shown for typical commercial services to large buildings in each of the three cities. The simplicity of the Sacramento installation together with the avoidance of the open delta connections as shown for San Jose and the three-wire secondary for each phase as shown for San Francisco are very noticeable.

The Sacramento system is in general much more flexible than either of the others and permits transformer banks to be removed for repairs or inspection without interruption to service by paralleling two or more adjacent banks and then pulling the links on the bank to be killed. The convenient and inexpensive method of paralleling the banks makes it desirable for carrying temporary loads during the daytime in cases where building contractors or others may desire 50 or 100 hp. three-phase for construction purposes. This eliminates the expense of installing separate transformer banks which on other systems generally have to be provided. Where a large block of load is supplied by one transformer, as generally is the case on the delta systems, the possibility of an extended interruption appears much greater owing to the lack of spare transformer capacity, than on a star system where any transformer failure easily can be taken care of by paralleling adjacent transformers.

The convenience of the star system for supplying three-phase loads cannot be over-estimated as the mains are always available for convenient connection without additional transformers or mains being installed.

An attempt was made to compare transformer losses and also transformer space utilized, but it was found that the information available did not permit. If these comparisons were to be made and if the comparisons as shown were to be more accurate, it would involve the obtaining of comparative information from a larger number of installations in existence from which a more dependable average could be obtained.

No attempt has been made in this article to discuss the subject of the four-wire interconnected secondary network because Sacramento's network is not of this type, although adjacent banks of transformers are operating in parallel where occasion requires.

Credit is given to C. W. Hutton, at one time division superintendent of the Pacific Gas and Electric Company, and to his brother, Olen Hutton, of his office, for most of the information contained in the early history of the Sacramento system.

Relative Advantages of Various Kinds of Ducts

By E. R. Northmore*

A questionnaire was sent to twelve of the operating member companies in the Pacific Coast Electrical Association. Replies have been received from nine and of these one has no underground system and another has but a very little. Of the remaining seven companies all were of the opinion that fiber duct had proved the more satisfactory, although there had been only a small amount of concrete duct used by any of the companies and that had been more in the form of an experiment.

Although very few tests had been made as to the resistance of concrete duct to the pulling of cable, it seems to be the general idea that concrete duct offers more resistance than does fiber duct; also that the abrasive action is greater. One of the companies had made cable-pulling tests in both fiber and concrete ducts and their results showed from 60 to 70 per cent higher pulling stress when pulling in concrete. Another company reports that greasing the cable apparently made no difference in the pulling stress in concrete ducts.

An effort was made to get some idea of the cost per trench-ft. from the different companies, but it seems that conditions vary so much with different locations, such as type of soil, number of obstructions, available space in the ground, etc., that any comparison is of practically no value. For a conduit section of nine 3½ or 4-in. fiber ducts, which seems to be a popular number of ducts, laid three wide and three deep, the costs vary from $4 to $5.75 in the different reports.

All of the reporting companies express preference for the 5-ft. lengths of duct, particularly in congested districts where corners and slight curves are required. However, the 8-ft. lengths have an advantage where there are long straight runs.

Two companies reported that they had made heat dissipation tests on both fiber and concrete and find that concrete duct dissipates slightly more heat than fiber, but that electrolytic action on lead-covered cable seems to be greater when it is installed in concrete.

A number of companies report trouble with the binder used in certain kinds of conduit due to its softening with the application of heat, causing the compound to run to the bottom of the duct, cementing the cable in and making it more difficult to pull out. The melting point of the compound occurred at about 140 deg. C., while in other makes of conduit it was 180 deg. None of the companies specified temperature tests on conduit when purchased.

One company reported that the earlier paper conduit which was installed a number of years ago had given trouble due to moisture softening the paper, causing it to swell and bind the cable so that it could not be pulled either in or out. This type of conduit has been

* Report presented to underground systems committee.

discontinued by all of the manufacturers and was one of the earliest types manufactured.

Tile duct has not met with any favor by any of the companies, although it is used extensively by the telephone companies throughout the country.

Operation of Single-Conductor Cables at 60 Cycles

By R. R. Cowles*

Losses in single conductor cables consist of the following:

1. I^2R in conductor (including "skin effect").
2. $I_1^2R_1$ due to induced current flowing in the metallic sheath or armor.
3. Eddy currents in conductor.
4. Eddy currents in the surrounding material.
5. Dielectric losses in the insulating material.

Skin effect, which is due to flux distribution in the conductor, is independent of the current density and varies with the frequency, size of conductor and method of stranding. This increases the effective resistance of the conductor, hence the I^2R loss and ohmic drop increase proportionately. The distance between phase conductors appears to have little if any influence on the skin effect; which is true also of all conditions external to the conductor surface such as conductor sheathing, armoring, etc. This apparently is borne out in tests made by Middleton & Davis[1] although it would appear that the distortion of magnetic field at close conductor spacing should increase somewhat the skin effect.

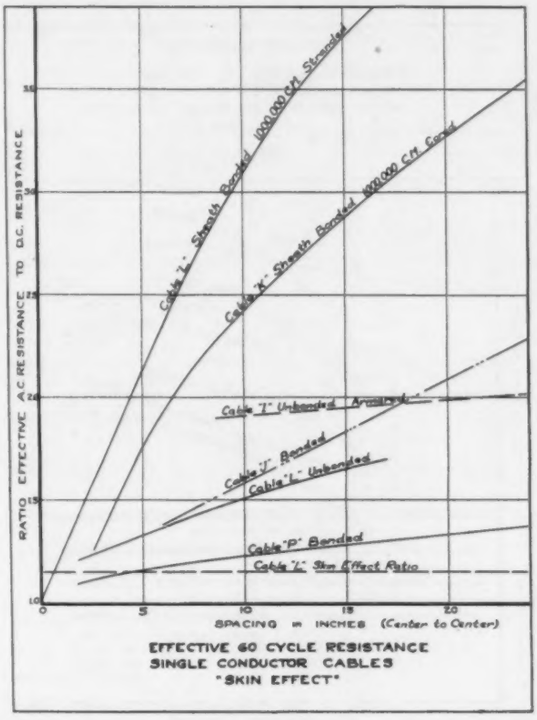

RATIO EFFECTIVE A.C. RESISTANCE TO D.C. RESISTANCE
Cable "L" Sheath Bonded 1000,000 Cir. Stranded
Cable "K" Sheath Bonded 1000,000 Cir. Cored
Cable "J" Unbonded Armored
Cable "J" Bonded
Cable "L" Unbonded
Cable "P" Bonded
Cable "L" Skin Effect Ratio
SPACING in INCHES (Center to Center)
EFFECTIVE 60 CYCLE RESISTANCE
SINGLE CONDUCTOR CABLES
"SKIN EFFECT"

Fig. 1.

It would seem, therefore, that for a given conductor the skin effect at 60 cycles will be the same whether leaded, armored, or unarmored and for all conditions of bonding of the surrounding conducting material**.

Eddy Currents in Conductor

There seems to be considerable difference of opinion regarding the magnitude of these losses. Clark and Shranklin[2] state that in 1,000,000 cir.mil stranded cables both test and calculations prove that the eddy current losses in the conductor are so small that they can be neglected.

H. W. Fisher mentions a test on a 500,000 circ.mil lead-covered cable in which the eddy current losses in the conductor were 7 per cent of the I^2R losses at 60 cycles (Trans. A.I.E.E. 1909, p. 766.)

Report No. 284, Bureau of Tests** shows by test an increase in effective resistance of a 1,000,000 circ.mil stranded conductor of 65 per cent above the d.c. resistance at 15-in. spacing. Skin effect (calculated) accounts for 15 per cent of this, but the remainder, representing 50 per cent increase in conductor losses, is difficult to account for as eddy currents in the conductor.

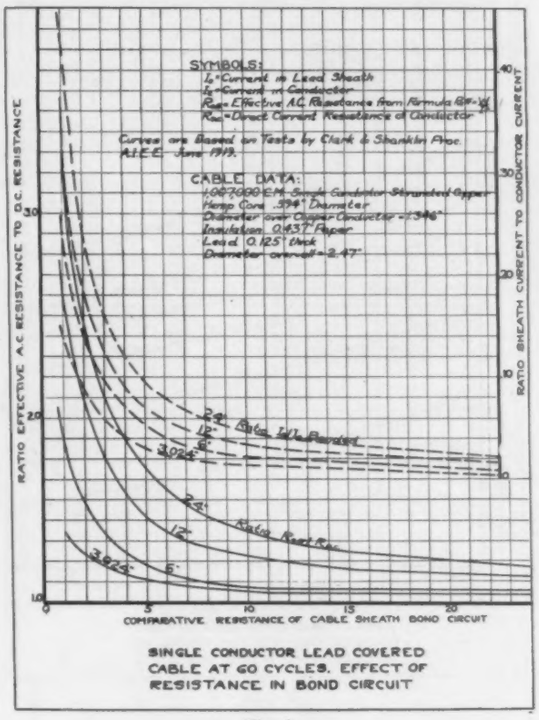

SYMBOLS:
Curves are Based on Tests by Clark & Shanklin Proc. A.I.E.E. June 1919.
CABLE DATA:
RATIO EFFECTIVE A.C. RESISTANCE TO D.C. RESISTANCE
RATIO SHEATH CURRENT TO CONDUCTOR CURRENT
COMPARATIVE RESISTANCE OF CABLE SHEATH BOND CIRCUIT
SINGLE CONDUCTOR LEAD COVERED
CABLE AT 60 CYCLES. EFFECT OF
RESISTANCE IN BOND CIRCUIT

Fig. 2.

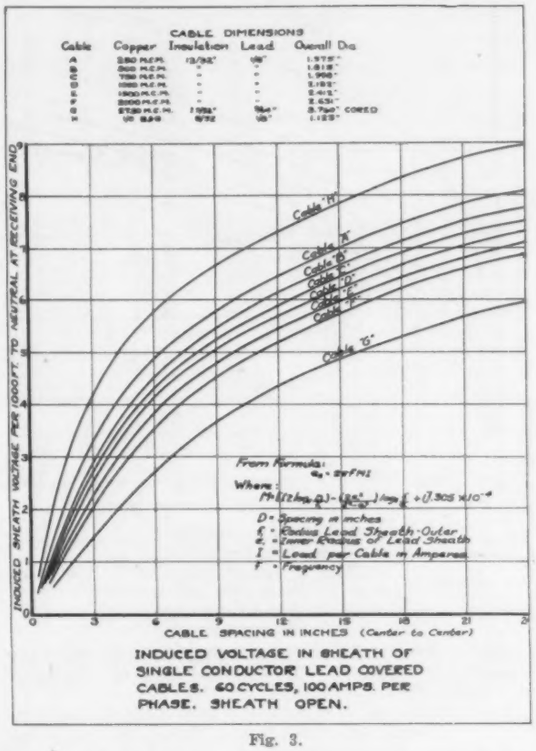
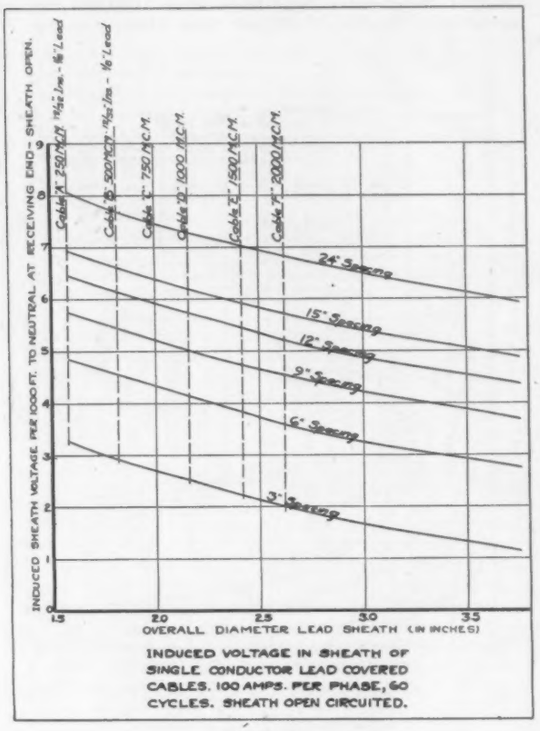

CABLE DIMENSIONS
INDUCED SHEATH VOLTAGE PER 1000 FT. TO NEUTRAL AT RECEIVING END
CABLE SPACING IN INCHES (Center to Center)
INDUCED VOLTAGE IN SHEATH OF
SINGLE CONDUCTOR LEAD COVERED
CABLES. 60 CYCLES, 100 AMPS. PER
PHASE. SHEATH OPEN.

Fig. 3.

* Report presented to underground systems committee.

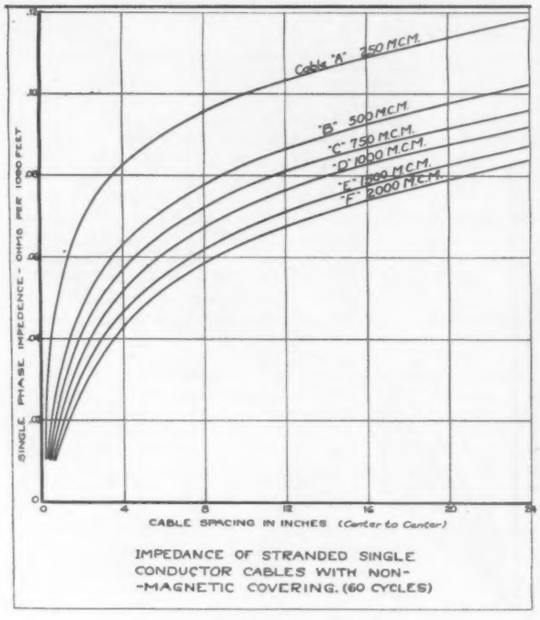
** See reference list at end of article.

Fig. 1 shows the result of these tests (cable "L"). The question arises as to why the conductor losses should increase so materially with the spacing.


INDUCED SHEATH VOLTAGE PER 1000 FT. TO NEUTRAL AT RECEIVING END - SHEATH OPEN.
OVERALL DIAMETER LEAD SHEATH (IN INCHES)
24" Spacing
15" Spacing
12" Spacing
9" Spacing
6" Spacing
3" Spacing

INDUCED VOLTAGE IN SHEATH OF SINGLE CONDUCTOR LEAD COVERED CABLES. 100 AMPS. PER PHASE, 60 CYCLES. SHEATH OPEN CIRCUITED.

Fig. 4.


SINGLE PHASE IMPEDENCE - OHMS PER 1000 FEET
CABLE SPACING IN INCHES (Center to Center)
Cable "A" 750 MCM.
"B" 500 MCM.
"C" 750 MCM.
"D" 1000 MCM.
"E" 1500 MCM.
"F" 2000 MCM.

IMPEDANCE OF STRANDED SINGLE CONDUCTOR CABLES WITH NON-MAGNETIC COVERING. (60 CYCLES)

Fig. 5.

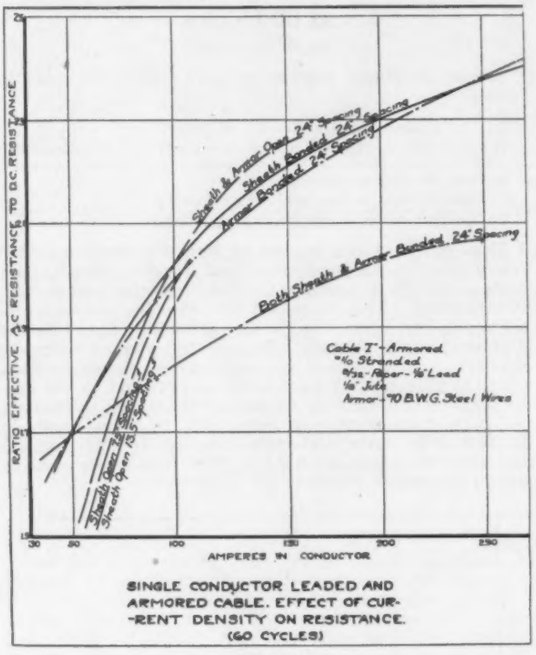
Eddy current losses in surrounding material will vary considerably with the material and will be discussed later under separate headings.

Dielectric losses vary with the operating voltage, insulating material and cable temperature. Below 7.5 kv. they usually can be neglected. This loss usually is specified in the manufacturer's guarantee or can be calculated from the formula of Clark and Shanklin**.

All losses, whether in the conductor, insulting material or metallic covering, reduce the carrying capacity of the cable inasmuch as all the heat generated must be dissipated from its surface.

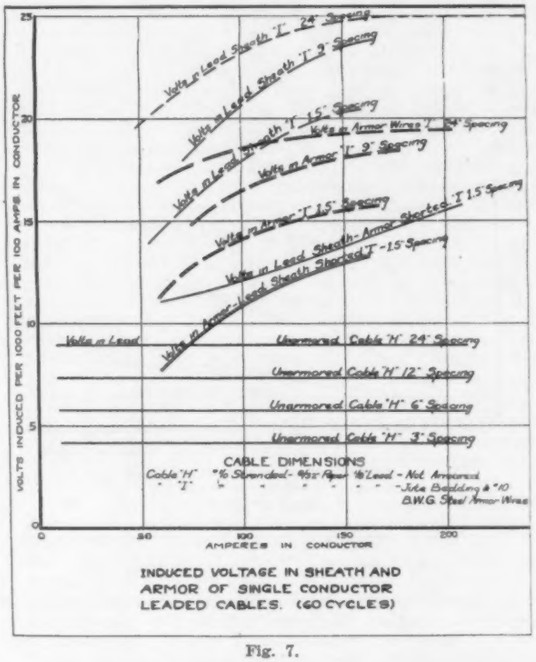
Single-Conductor Cables With Non-Magnetic Sheath

These have the same reactance and impedance as uncovered cables and the voltage induced per unit length in the unbonded sheath (if metallic) should vary


RATIO EFFECTIVE A.C. RESISTANCE TO D.C. RESISTANCE
AMPERES IN CONDUCTOR
Both Sheath & Armor Bonded 24" Spacing
Cable "I" - Armored
"/0 Stranded
Armor - "10 B.W.G. Steel Wires

SINGLE CONDUCTOR LEADED AND ARMORED CABLE. EFFECT OF CURRENT DENSITY ON RESISTANCE. (60 CYCLES)

Fig. 6.


VOLTS INDUCED PER 1000 FEET PER 100 AMPS IN CONDUCTOR
AMPERES IN CONDUCTOR
Volts in Lead Sheath "L" 24" Spacing
Volts in Lead Sheath "L" 9" Spacing
Volts in Lead Sheath "L" 15" Spacing
Volts in Armor Wires "L" 24" Spacing
Volts in Armor "L" 9" Spacing
Volts in Armor "L" 15" Spacing
Volts in Lead Sheath-Armor Shorted "L" 15" Spacing
Volts in Armor-Lead Sheath Shorted "L" 15" Spacing
Volts in Lead
Unarmored Cable "H" 24" Spacing
Unarmored Cable "H" 12" Spacing
Unarmored Cable "H" 6" Spacing
Unarmored Cable "H" 3" Spacing
CABLE DIMENSIONS
Cable "H" "/0 Stranded - 4/32" Paper - 1/16" Lead - Not Armored
" "I" " " " " " " " - Jute Bedding & "10 B.W.G. Steel Armor Wires

INDUCED VOLTAGE IN SHEATH AND ARMOR OF SINGLE CONDUCTOR LEADED CABLES. (60 CYCLES)

Fig. 7.

directly as the current flowing in the conductor. The above is substantiated by tests and calculations made by Clark and Shanklin, and by calculations made by E. J. Berg**.

In Figs. 3, 4 and 5 are shown curves representing induced sheath voltage and impedance of various single-conductor cables with non-magnetic sheaths, based upon calculations in which the permeability of the surrounding material has been taken as unity.

** See reference list at end of article.

** See reference list at end of article.

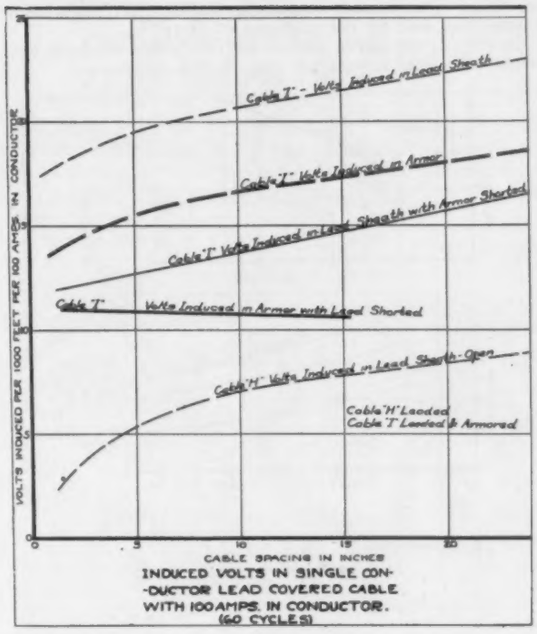

Cable "I" - Volts Induced in Lead Sheath
Cable "I" Volts Induced in Armor
Cable "I" Volts Induced in Lead Sheath with Armor Shorted
Cable "I" Volts Induced in Armor with Lead Shorted
Cable "H" Volts Induced in Lead Sheath Open
Cable "H" Loaded
Cable "I" Loaded & Armored
VOLTS INDUCED PER 1000 FEET PER 100 AMPS. IN CONDUCTOR
CABLE SPACING IN INCHES
INDUCED VOLTS IN SINGLE CONDUCTOR LEAD COVERED CABLE WITH 100 AMPS. IN CONDUCTOR. (60 CYCLES)

Fig. 8.

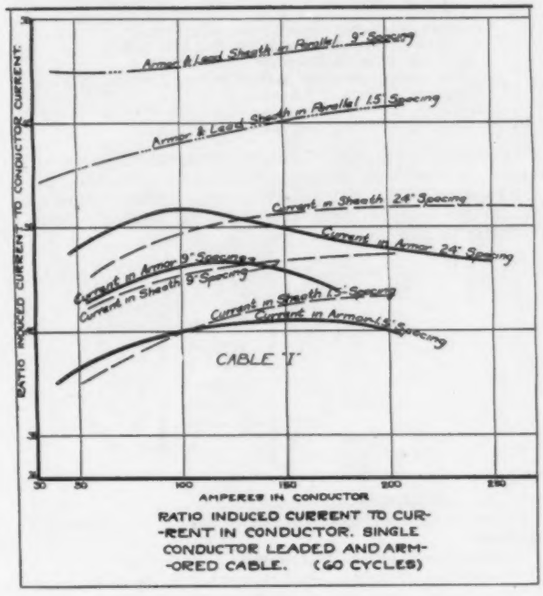

Armor & Lead Sheath in Parallel 9" Spacing
Armor & Lead Sheath in Parallel 15" Spacing
Current in Sheath 24" Spacing
Current in Armor 24" Spacing
Current in Armor 9" Spacing
Current in Sheath 9" Spacing
Current in Sheath 15" Spacing
Current in Armor 15" Spacing
CABLE "I"
RATIO INDUCED CURRENT TO CONDUCTOR CURRENT
AMPERES IN CONDUCTOR
RATIO INDUCED CURRENT TO CURRENT IN CONDUCTOR. SINGLE CONDUCTOR LEADED AND ARMORED CABLE. (60 CYCLES)

Fig. 9.

Reactance is calculated from the formula:

$$X = 2\pi f \left\{ \frac{30.5}{10^6}(2 \log_e \frac{2D}{d} + \frac{1}{2}) \right\} \text{ where:}$$

X = reactance ohms per 1,000 ft. of conductor, single phase.

f = 60 cycles per second.

D = spacing between conductors (inches) center to center.

d = diameter of conductor (inches).

Induced sheath voltage to neutral per 1,000 ft. of conductor is calculated from the formula of Clark and Shanklin.

$$e_s = 2\pi f I M \text{ where:}$$

I = amp. in conductor (R.M.S.)

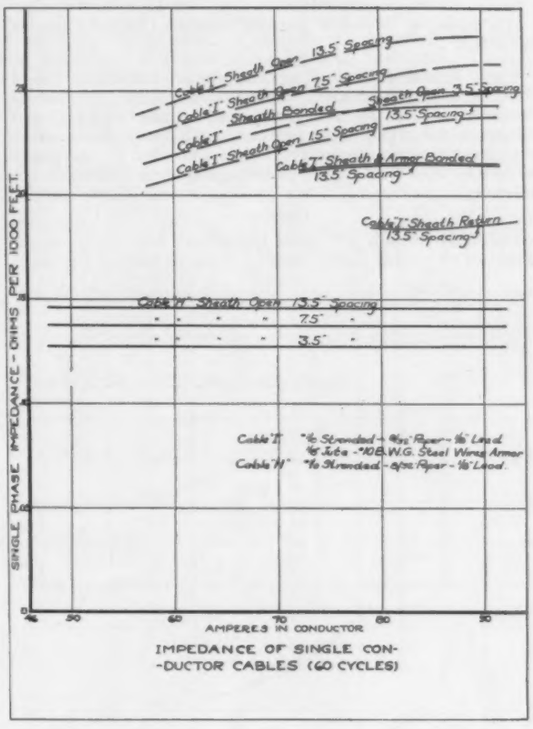

Cable "I" Sheath Open 13.5" Spacing
Cable "I" Sheath Open 7.5" Spacing
Cable "I" Sheath Open 3.5" Spacing
Cable "I" Sheath Bonded 13.5" Spacing
Cable "I" Sheath Open 15" Spacing
Cable "I" Sheath & Armor Bonded 13.5" Spacing
Cable "I" Sheath Return 13.5" Spacing
Cable "H" Sheath Open 13.5" Spacing
7.5"
3.5"
Cable "I" 3/0 Stranded - 4/64" Paper - 1/8" Lead. 1/8" Jute - .104 B.W.G. Steel Wire Armor
Cable "H" 3/0 Stranded - 4/64" Paper - 1/8" Lead.
SINGLE PHASE IMPEDANCE - OHMS PER 1000 FEET
AMPERES IN CONDUCTOR
IMPEDANCE OF SINGLE CONDUCTOR CABLES (60 CYCLES)

Fig. 10.

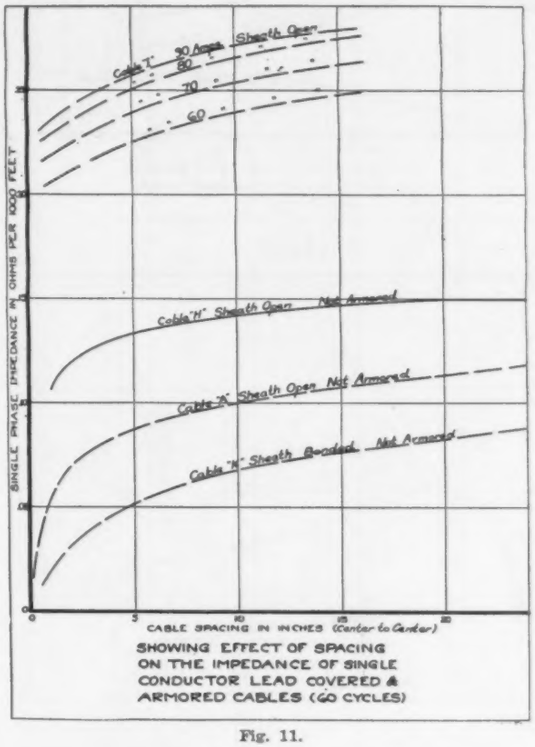

Cable "I" 90 Amps. Sheath Open
80 "
70 "
60 "
Cable "H" Sheath Open Not Armored
Cable "I" Sheath Open Not Armored
Cable "H" Sheath Bonded Not Armored
SINGLE PHASE IMPEDANCE IN OHMS PER 1000 FEET
CABLE SPACING IN INCHES (Center to Center)
SHOWING EFFECT OF SPACING ON THE IMPEDANCE OF SINGLE CONDUCTOR LEAD COVERED & ARMORED CABLES (60 CYCLES)

Fig. 11.

M = mutual inductance between conductor and sheath per 1,000 ft. of length.

$$M = \frac{0.305}{10^4} \left\{ (2 \log \frac{D}{f_1}) - (\frac{2e_1^2}{f_1^2 - e_1^2} \times \log_e \frac{f^1}{e_1}) + 1 \right\}$$

where:

f_1 = ½ outside diameter of lead sheath (inches).

e_1 = ½ inside diameter of lead sheath (inches).

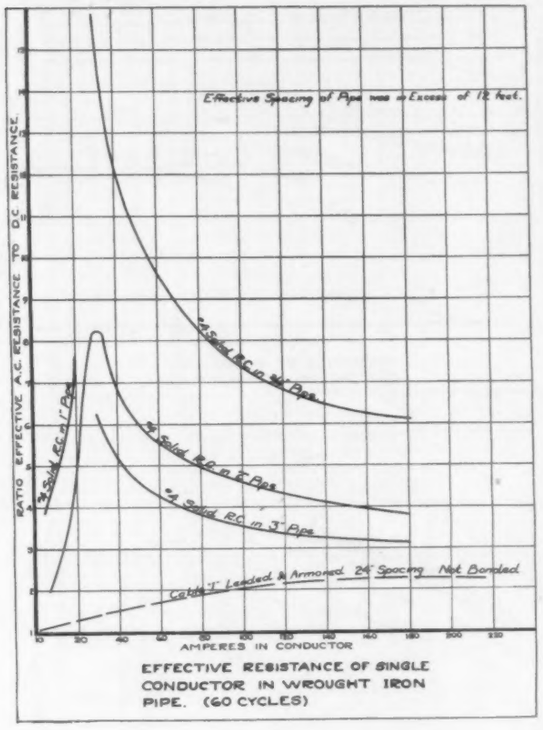
D = spacing between parallel cables (inches) center to center.

Figs. 3 and 4 show that the induced voltage for a given spacing decreases with cables of larger overall diameter, while the reactance, impedance and induced voltage for a given cable increase with the spacing. The lead sheath when open circuited, i.e., bonded at one point only, has no effect upon the reactance or effective resistance.

Losses

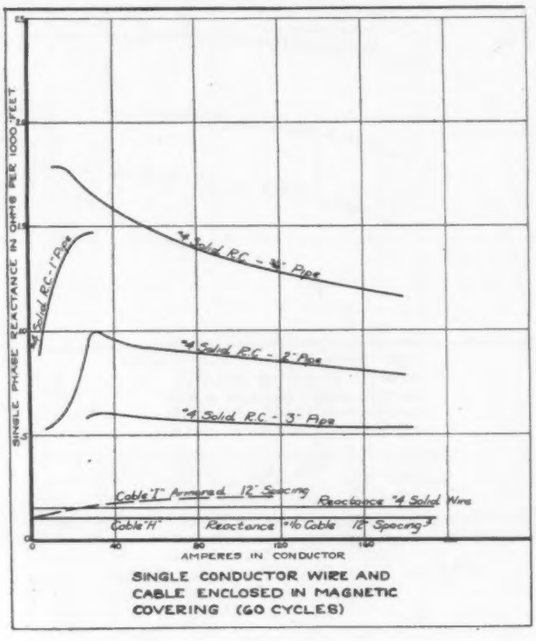
The lead sheath (if open circuited) has little or no effect on the total cable losses. This is proved by tests made by Clark and Shanklin, Bureau of Tests and Inspection, and by calculations of Berg**.

In Fig. 1, the curve for cable "L" (unbounded) is the same with lead sheath as with sheath removed.


RATIO EFFECTIVE A.C. RESISTANCE TO D.C. RESISTANCE
Effective Spacing of Pipe was in Excess of 12 feet.
#4 Solid R.C. in ¾" Pipe
#4 Solid R.C. in 2" Pipe
#4 Solid R.C. in 3" Pipe
Cable "I" Leaded & Armored 24" Spacing Not Bonded
AMPERES IN CONDUCTOR

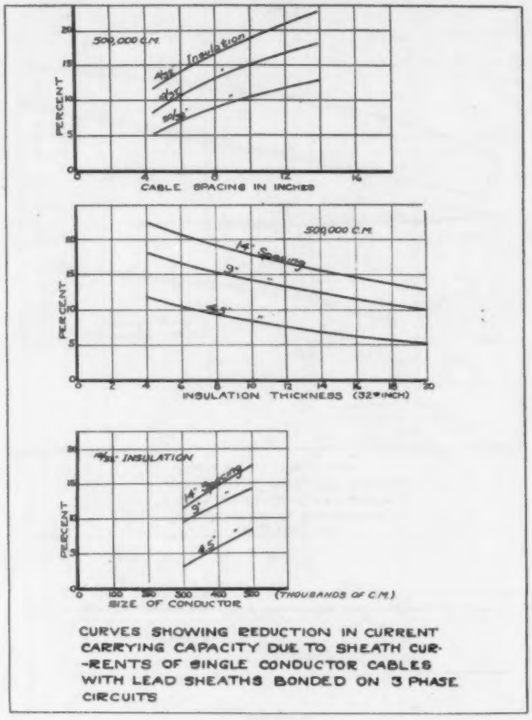
EFFECTIVE RESISTANCE OF SINGLE CONDUCTOR IN WROUGHT IRON PIPE. (60 CYCLES)

Fig. 12.


SINGLE PHASE REACTANCE IN OHMS PER 1000 FEET
#4 Solid R.C. - ¾" Pipe
#4 Solid R.C. - 2" Pipe
#4 Solid R.C. - 3" Pipe
Cable "I" Armored 12" Spacing
Reactance #4 Solid Wire
Cable "H" Reactance #1/0 Cable 12" Spacing
AMPERES IN CONDUCTOR

SINGLE CONDUCTOR WIRE AND CABLE ENCLOSED IN MAGNETIC COVERING (60 CYCLES)

Fig. 13.



CURVES SHOWING REDUCTION IN CURRENT CARRYING CAPACITY DUE TO SHEATH CURRENTS OF SINGLE CONDUCTOR CABLES WITH LEAD SHEATHS BONDED ON 3 PHASE CIRCUITS

Fig. 14.

There may be a slight amount of circulating current induced in the lead sheath when open circuited, due to unsymmetrical flux distribution. The following formula by Berg** gives the value of effective resistance due to this loss:

$$r_{eff} = r_c + \left(\frac{f^2 L^2}{r_s \times 10^2}\right) \qquad \text{where:}$$

$$L = \frac{32}{10^4} \log_e \left\{ \frac{D + \frac{D_1}{4}}{D - \frac{D_1}{4}} \right\}$$

where:

r_c = a.c. resistance of conductor.

r_s = resistance of lead sheath in terms of conductor resistance.

f = frequency, cycles per second.

D = spacing of cables, inches, center to center.

D_1 = outside diameter of lead sheath (inches).

From the above formula, with a conductor of 1-in. diameter and 4-in. spacing, the eddy current losses in the lead sheath increase the effective resistance 0.353 per cent at 60 cycles.

In opposition to the above statements, H. W. Fisher reports (A.I.E.E. June, 1909) that a test on a 500,000-circ.mil cable at 60 cycles showed eddy current losses in the lead sheath to be 6 per cent of the I^2R losses.

** See reference list at end of article.

References

1. High Tension Single Conductor Cable for Polyphase Systems, by Clark and Shanklin, A.I.E.E. 1919—Part 1.
2. Skin Effect in Large Stranded Conductors at Low Frequencies, by Middleton and Davis, Journal A.I.E.E., September, 1921.
3. Constants of Cables and Magnetic Conductors, by E. J. Berg, A.I.E.E., 1907—Part 1.
4. Resistance and Reactance of Armored Cables, by J. B. Whitehead, A.I.E.E., 1909—Part 2.
5. Losses, Induced Volts and Amperes in Armor and Lead Cover of Cables, by H. W. Fisher, A.I.E.E., 1909—Part 2.
6. Report No. 284, Bureau of Tests and Inspections, Pacific Gas and Electric Company, Sept. 22, 1921. "Losses in Sheath and Conductor of Lead Covered Single Conductor Cables."

Joint Underground Construction for Telephone and Electric Distribution Lines

By Clayton Biggs*

The practice of joint construction of underground distribution systems in real estate subdivisions, as successfully used in southern California, was brought about through the hearty co-operation of the telephone and power companies' engineers, representatives of contractors and subdividers. The thought in mind was to lower the cost of construction and at the same time have a standardized and lasting underground system sufficient for the needs of the utilities involved.

The actual start of this type of construction was made in the field on subdivisions where the land was hilly and rough and where the cost of separate systems would be prohibitive. The representatives of all parties concerned would meet and go over the ground in an

* Report presented to underground systems committee.

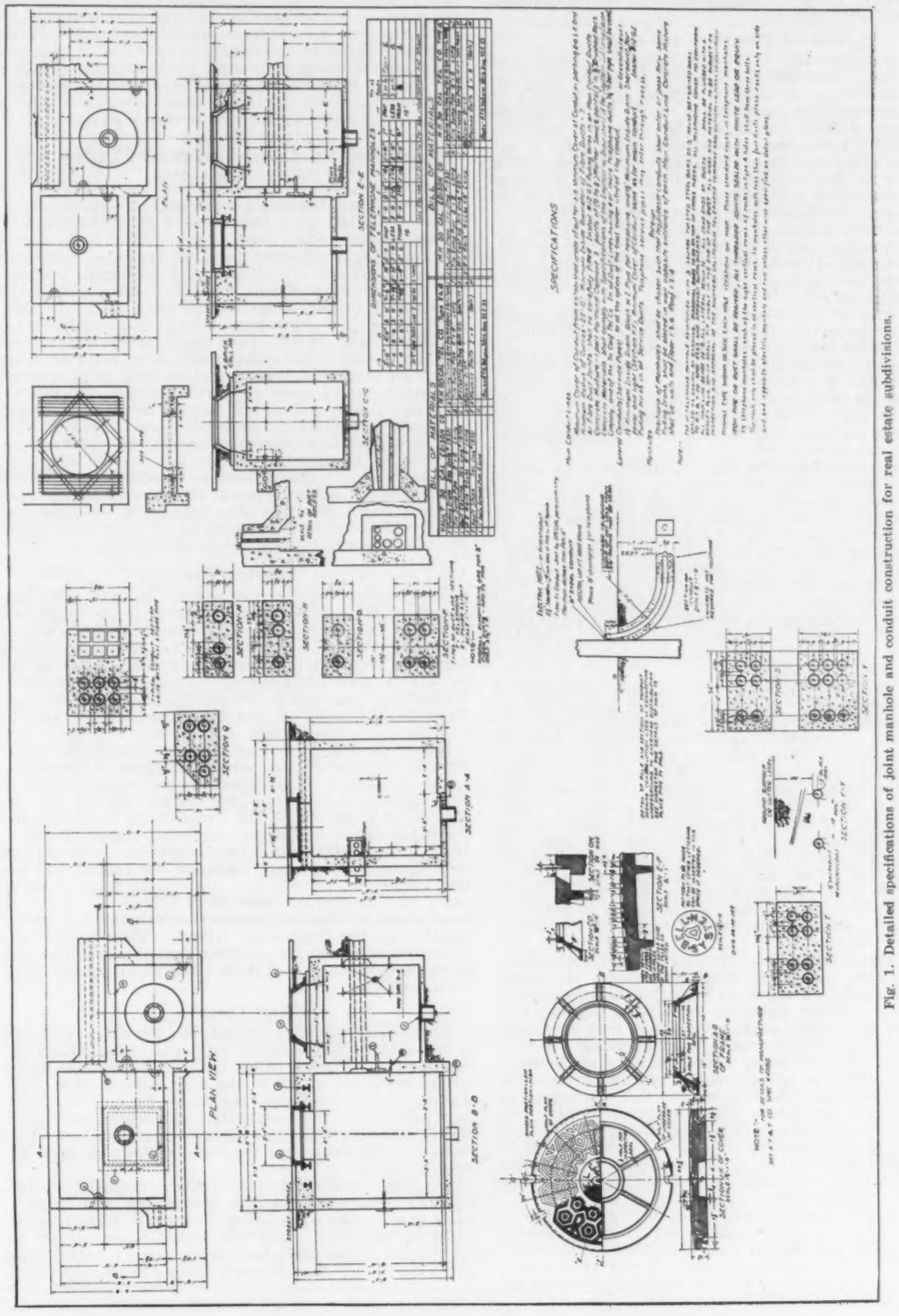


Fig. 1. Detailed specifications of joint manhole and conduit construction for real estate subdivisions.

effort to lay out a system at as low a cost as consistent with good material and workmanship.

After several installations had been made in this way it was thought best to make a tentative standard layout of joint construction. This was first made by the telephone company engineers and was checked and revised several times by both the telephone and the electric company before being adopted as a standard print for the construction of underground services in subdivisions. Much credit is due to the telephone engineers and to some of the contractors engaged in this class of work, for the preparation of this standard plan and specification.

General Procedure and Costs

When a subdivider or owner wishes an underground installation, a map of the tract is furnished to either the telephone or the electric company, or possibly to some contractor engaged in the work, for layout and estimates of cost. Although the telephone company will furnish estimates on telephone cable only, it will at times make up a layout and submit it to the electric company for approval and for the furnishing of a complete estimate of cost (except telephone cables) to the subdivider. The subdivider then in turn has the option of submitting the plans of the conduits, manholes and vaults to some reliable contractor for further estimate with the understanding that the electric company and telephone company will furnish estimates for cable installation only.

The map of the property to be subdivided should preferably be an officially recorded map showing streets, alleys and lot lines, in order that the distribution system can be laid out properly and correct working blue prints made. A tracing of the map submitted is made first and the utilities shown in place, preferably in the streets or alleys although many systems are installed along rear lot lines. In the latter case an easement or right-of-way is required.

If a contractor is doing the construction work and is dealing directly with the owner or subdivider (plans having been formally approved by both utilties) a notice is sent to both companies giving the date that the work is to be commenced. An inspector then is placed on the job by one of the utilities and in case of a large installation it is customary for both utilties to have an inspector in the field continuously in order to see that the plans and specifications are being followed. While there is no set agreement between the companies as to who will furnish the inspector it is generally understood that the interests of both companies will be looked after by the inspector.

Upon completion of the work by the contractor a notice of completion with a request for a final inspection and letter of acceptance is forwarded to both companies with a corrected map, showing distances between manholes, length of service laterals and any changes that may have been necessary. Permanent markers are required in order to show the location of the end of the service lateral. This can be done by stakes or markings on curbs, if already installed, or by means of an iron pipe approximately 3 ft. long with an iron ring attached to one end. This ring is slipped over the end of the lateral before the pipe cap is screwed on, with the pipe in a vertical position projecting about 18 in. above ground. This marker is not removed until the conduit is extended to the meter location by the wiring contractor.

If the entire job is to be handled by the electric company (always excepting telephone cables) the usual tracing is made and approved by both companies, specifications are written and notes made regarding any city or county ordinances or permits which may be necessary, also any railroad crossing and anything else that may be out of the ordinary. Blue prints are made showing both utilities in place and any special construction work is shown in detail. Competitive bids are requested from various contractors who are qualified and who more or less specialize in this class of work. The successful bidder is required to post a bond equal to 50 per cent of the contract price to assure the faithful performance of the work and to complete the work within the specified time.

In all cases where the underground system has been installed prior to the establishment of street grades the companies stipulate in their acceptance of the work that they will not go to any expense in raising or lowering castings in case they are not to grade when subsequent street improvements are made. The estimate furnished by the electric company to the owner or subdivider of the tract usually is made up of separate costs, one cost for telephone and electric manholes, vaults, conduits and service laterals, and another cost for the electric cables, both primary and secondary, installed. The transformers and other equipment are not included as these are installed at the company's expense as the tract is built up and service is requested.

Except in rare cases the cable installation is made by the company with its own forces. However, when installed by a contractor the installation must be made under company supervision and all cable and equipment are subjected to voltage tests upon completion of the work and before acceptance by the company. All details pertaining to the actual installation of the complete job including estimates, plans and specifications are handled by the underground branch of the operating department. Commercial contracts, deposits and refunds are handled by the commercial department.

Testing Lead-Covered Cables

By C. G. Mansfield*

Pacific Coast practice in the testing of lead-covered cables is reflected in the answers to a questionnaire on the subject which have been received from five of the operating companies using underground cable. Of these, all but one reported using the megger in checking the insulation of newly installed cable and several also use it in verifying cable faults. Only one company reported making high-voltage tests on newly installed cables. In this case the kenotron set is used and both installation and periodic proof tests are made on cables of the transmission class only. Three of the companies report some use of bridge methods in locating cable faults and all but one use a commercial type of "fault finder" for the same purpose.

The megger is a commercially available, portable set adapted to the approximate measurement of very high resistance, particularly insulation resistances. It will readily detect certain types of defective construction or failures which result in abnormally low insulation resistance, but must be followed up by other methods to locate the point at which the fault exists.

Kenotron Tests

The kenotron has been in use for several years as a source of high-voltage direct current for testing lead-covered cables. Some tests made by the Philadelphia Electric Company in 1922 suggested the possibility of detecting incipient failures in cables by observing the variations in charging current during periodic kenotron tests at approximately the normal operating voltage. Subsequent experience has failed to demonstrate the usefulness of this method.

Kenotron tests have been made on the 33-kv. transmission cables of the Los Angeles Bureau of Power and Light at more or less regular intervals since the lines were placed in service. The set and its use are described on page 277 of the Proceedings of the Pacific Coast Electrical Association for 1927. Up to March 1, 1928, a total of seven cable failures has occurred on these lines. The interval between the failure and the last previous kenotron test has varied from 6 to 78 days, with an average interval of 32 days. In more of these cases has the kenotron test shown any definite indication of the impending failure. This would seem to be rather conclusive evidence that the kenotron test as at present made is of little value as an indication of cable condition.

Fault Location

Since cable failures cannot be prevented entirely, it is essential that methods be available for accurately locating such faults with the least possible delay. Bridge tests are useful in the case of long, small conductors and definite, low resistance faults. They are less reliable on the very large conductors, and practically ueseless when the conductors are burned off or separated as usually is the case in failures of high-voltage cables.

The "fault finder" mentioned is a commercially available set commonly used in identifying and locating cable faults. An alternating current of peculiar wave form is impressed upon the faulty conductor by an interrupter. The fault then is located by determining the point on the line at which the signal disappears or

* Report presented to underground systems committee.

undergoes an abrupt decrease in volume, as determined by a suitable detector.

For cable work this detector usually consists of a sector-shaped core and coil which is placed in close contact with the cable sheath, an amplifier, and a telephone headset. The impressed signal is maintained at a constant intensity and observations are made in the various manholes on the line until the faulty section is found. Considerable care must be used in interpreting the indications because of the effects of the sheath and interference from other nearby power cables. In many cases very definite indications of a ground are obtained at a point at which no ground actually exists. This is particularly true in the case of high-voltage cable failures in which the sheath is blown open and the fault resistance is very high. If the test signal is stepped up to a voltage high enough to get an appreciable current through such a fault, the charging current becomes so great that the change in signal intensity at the fault is not sufficient to give a definite indication. Very much more satisfactory results will be obtained if the fault first is burned to a low resistance by the application of a relatively high voltage, and the signal test then made at a voltage of approximately 100 volts.

Operation of Substructure Committees

By H. G. Keesling*

From replies to the questionnaire sent out by the subcommittee studying electrolysis of underground lead-covered cables, it appears that only two regularly constituted committees for dealing with the problems of protection to underground structures exist in the territory covered by this association, one in Los Angeles and one in Oakland.

No information as to the scheme of organization and operation of the Los Angeles committee as yet has been obtained. The secretary of the Oakland committee has prepared a short report on the history and accomplishments of that committee. This report in full follows:

The Joint Committee for the Protection of Underground Structures in the East Bay Cities

By THOS. F. BABCOCK, Key System Transit Company, Secretary of the Committee.

The East Bay cities extend along the eastern shore of San Francisco Bay for a distance of approximately 20 miles, practically a continuously populated area. Transportation is furnished these cities by electric street car and interurban lines of the Key System Transit Company, the Southern Pacific Company and the San Francisco-Sacramento Railroad Company. Other utilities serving this area are the East Bay Water Company, the Pacific Gas and Electric Company, the Western Union Telegraph Company, The Pacific Telephone and Telegraph Company, the Postal Telegraph-Cable Company and the Great Western Power Company of California.

Reference to the accompanying map shows the railroad and street car lines in this area and also shows the location of 13 substations and one steam plant which supply electric power for the operation of these lines. Prior to 1925 three of these substations did not exist. At that time Station L of the Pacific Gas and Electric Company, in the center of Oakland, was put in operation to supply power to the Key System. During that same month the Key System Transit Company put in operation its automatic substation, shown near its pier terminal. In August, 1926, Station O of the Pacific Gas and Electric Company, an automatic railway substation, was put in operation. This station is located between San Leandro and Hayward near the end of a long single-track line and was found to be a big factor in reducing electrolytic action on undergrorund structures.

Previous to the organization of the committee each of the utilities operating underground plants that were subject to damage by electrolytic action had been making independent investigations and establishing independent corrective measures. The result was great duplication of effort on the part of the utilities concerned. Also, what might prove beneficial to one often was found to be detrimental to the others.

In December, 1922, representatives from all of the above mentioned utilities and a representative from the electrical department of the City of Oakland met and organized a joint committee. By the plan of organization a general committee is composed of one representative from each of the utilities and one from the City of Oakland. These members are designated to serve by their respective companies and are appointed annually. The general committee meets once a year, at which time a chairman and secretary-treasurer are elected to serve for one year. The general committee at that time also elects a technical committee of five members, who may or may not be members of the general committee. This technical committee meets monthly and has direct charge of all work and corrective measures performed by the committee.

The utilities represented on the general committee furnish the technical committee with funds, men for test work, equipment, etc., as needed, each supplying what is available and generally in proportion to the amount of benefit derived by each. The field force, working under the direction of the technical committee, consists of a foreman and from five to twelve men whose services are loaned by the general committee. Salaries and wages of all on committee work are paid by their respective companies, they being loaned to the committee for the mutual benefit of all concerned.

Headquarters of the committee are at the offices of the Key System Transit Company. There the secretary-treasurer keeps a record of all activities and sends out to all members a monthly report of work done. Minutes of monthly meetings of the technical committee also are sent to all members.

The first work performed after organization was a general survey of the entire East Bay territory, particularly as regards potential differences and current flow between various underground structures such as railroad tracks, water pipes, gas pipes and power and telephone cables. Potential-gradient readings were taken along the more important railroad lines. Existing current drainage connections were located and either repaired or removed, as proved best. New current drains also were installed at definite points where

* Report presented to underground systems committee.

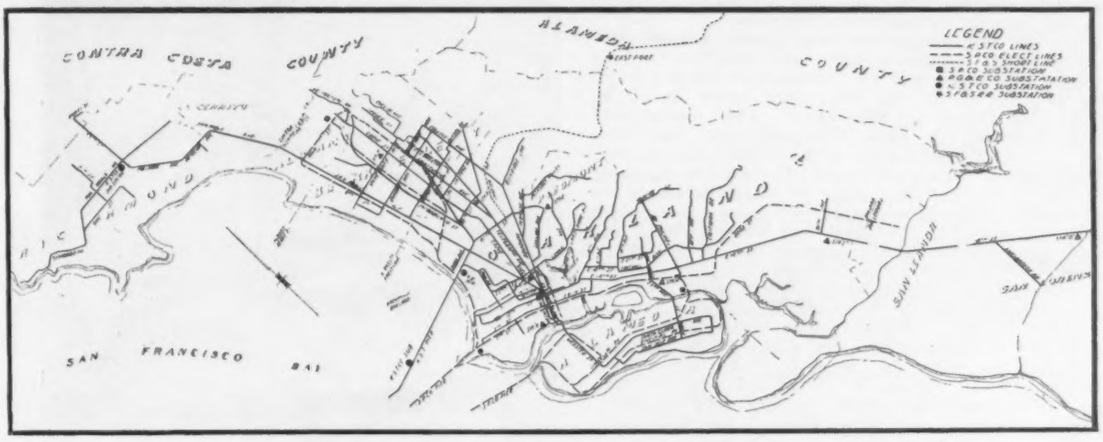


Fig. 1. Area covered by (San Francisco) East Bay cities underground structure joint committee.

testing indicated the need.

During 1924 the general survey was continued, special attention being given to the territory around railway substations in West Oakland, First and Grove Sts., Temescal, Fruitvale and Twenty-fourth Ave. in East Oakland. Several cross ties were installed between underground structures as also were several drainage stations. Readings were taken on joint bonding on some of the electric lines.

In 1925, as previously stated, several new substations were put in operation. Complete surveys were made in each of these localities both before and after the substations went into service. Any changes in conditions on underground structures caused by the operation of these substations therefore could be noted and taken care of. At the same time permanent drainage and test stations were installed in manholes near these substations.

In 1926 work was continued much as in the past. In addition to this work it was decided to take monthly readings of current flow on all drain cables, noting changes as they occur. These readings are included in the monthly reports. A large part of the time was spent on special cases of trouble that were turned over to the committee for investigation.

From time to time, some one of the utilities will have a case of corrosion on pipes or cables which there may be reason to believe to be caused by electrolytic action. Such cases are turned over to the committee for investigation. A report of facts as found is rendered at the next meeting of the technical committee. The matter then is discussed in meeting and the field force instructed as to what corrective measures should, in the opinion of the committee, be made.

Reviewing the work of the past years, it has been found that concerted action by those affected, co-operative study of conditions and consolidation of efforts in establishing mitigative measures have resulted in actual decrease in failures attributable to electrolysis. It is not believed that there is a complete solution to the problem, that is, that electrolytic corrosion caused by stray currents can be stopped completely, once and for all. But, it is known that mutual understanding and mutual effort on the part of all concerned will reduce electrolytic corrosion on underground structures to a minimum.

Telephone Communication Between Manholes

By N. B. Hinson*

The original underground system at Long Beach, Calif., was installed in the business district which was approximately one mile from the substation. When the load growth demanded an extension of the underground system it also called for the building of a new substation in the center of the business district. Experience with this and other underground systems led to the belief that the ability to talk between transformer vaults and between vaults and the substation, especially as the system grows, would be of great advantage. This system then was operating at 2.3 kv. and it was planned to cut it over to 4 kv. within a year or so and the communication system would be of material help in making these cutovers.

When the additions to the underground system were made a 3-pair telephone cable was installed between the new substation and all transformer vaults. This cable consists of six No. 19 copper wires rubber insulated and rated at 250 volts. Two wires were twisted together to form the pairs and the three pairs cabled together with a jute filler wound with a single tape and then sheathed. The outside diameter is 9/16 in. so that the cable is small compared to power cable. This cable cost approximately 9 cents per ft. It is installed in the same duct with the light and power secondary and is handled as a secondary throughout the underground system.

All the joints are wiped and filled similar to the secondary power cable. A special terminal was made for connecting the telephone leads to the cable, consisting of a short piece of tinned copper tube threaded on one end and wiped to the cable at the other. On the threaded end a type "H" condulet is attached and a special fibre terminal with two lugs for attaching the telephone cord is mounted inside. The cable ends are filled with compound inside this fitting. All of this equipment was made in the company's own underground shop as it was special and more or less experimental.

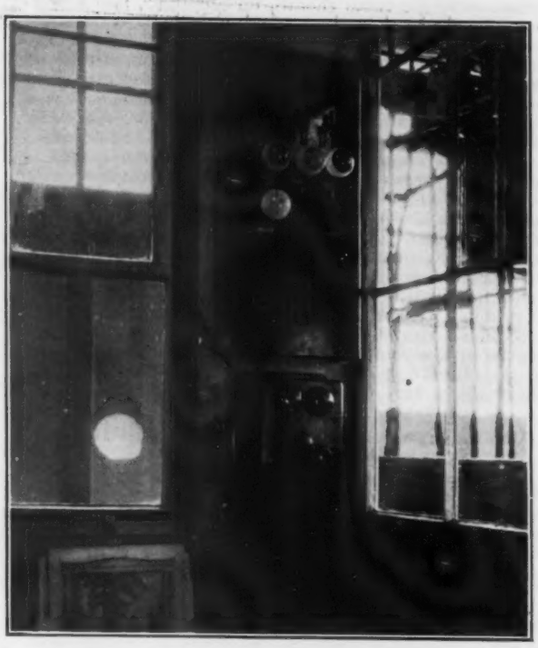


Fig. 1. Underground telephone and accompanying telltale lamps in the operating room at a substation.

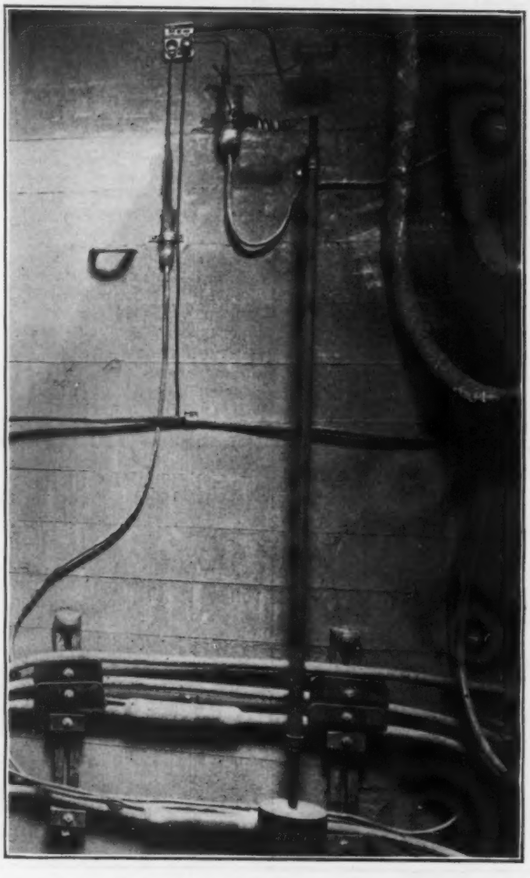


Fig. 2. Float alarm installed in a transformer vault.

* Report presented to underground systems committee.

A standard, portable, bridging magneto-type telephone is used. This is similar to the ones used on high-line work and is attached with a cord equipped with test clips. At the substation a similar wall-type telephone is installed. This is shown in Fig. 1. A system of code ringing is used to call the station or to call men in other vaults.

The 2.3-kv. system since has been changed over to 4 kv. and the saving in time and interruptions justified the expense of installing the telephone system. The telephone system at present utilizes only one of the pairs and the fact that the other wires were available suggested their use for another purpose which has worked out very satisfactorily.

Long Beach is located on very level ground and the drainage is difficult and considerable difficulty has been experienced from flooded transformer vaults during the rainy season. A special tell-tale system has been worked out, using a float and contact in the transformer vaults and one of the telephone wires back to the station, the other side of the circuit being the common ground throughout the underground. Details of the float in the transformer vault are shown in Fig. 2. Since this photograph was taken an inverted galvanized iron can has been attached to the wooden float on the bottom of the rod because occasionally a wooden float became water-soaked and did not operate. The can gives an upward pressure of 15 lb. when the float is flooded. The float is approximately 12 in. from the floor of the vault. At the station end tell-tale lamps are installed just above the underground system telephone, as shown in Fig. 1.

The vaults are grouped in sections, there being four groups at present with approximately ten vaults in each group. The Long Beach underground system at present consists of 45 transformer vaults and 160 manholes. As extensions are made the telephone and the float tell-tale systems are extended with it.

Ventilation of Transformer Vaults

By R. C. Powell*

With increasing transformer capacity necessary to supply an underground secondary system the problem of vault size and methods for dissipating the heat arising from transformer losses is becoming of great importance.

The heat that can be dissipated from a subway vault depends to a large extent upon climate, soil conditions, and type of pavement and will be greatly affected by the proximity of nearby duct lines, vaults, and steam mains. The heat is transmitted from the inside air through the vault walls, soil, and pavement to the outside air, and hence is directly proportional to the difference in these two air temperatures. Due to the large thermal capacity of the vault and soil, average values must be used since daily and seasonal variations occur for outside air temperature.

One company reports the results of some experiments to determine the dissipating ability of vaults. Electric heaters were put in the vaults and it was found that for manholes about 7 x 7 x 6.5 ft. inside dimensions from 45 to 60 watt-hr. per hour per deg. C. difference in air temperature could be dissipated without ventilation. The variation was due to different locations and this gives some idea of the effect of unknown variables.

Just what maximum transformer capacity can be installed in a vault of this size depends upon the average outside air temperature and the load factor. This company has been operating for a number of years with such vaults containing up to 125 kva. in transformer capacity.

* Report presented to underground systems committee.

With a cover ventilated with 113⅞-in. holes or about 68 sq.in. and with no cold air inlet the vault was found to dissipate 94 watt-hr. per hour per deg. C. The addition of a grating cover to admit cold air which was led through a pipe to the bottom of the vault increased the dissipation factor to 100 watt-hr.

The experiment also was tried of running a pipe from the vault to the curb and 14 ft. up a pole to get chimney effect. As would be anticipated, due to the chimney action, the dissipation factor increased with increasing vault air temperature and in the test made was 104 and 118 watt-hr. for air temperatures of 30 and 43 deg. C. respectively.

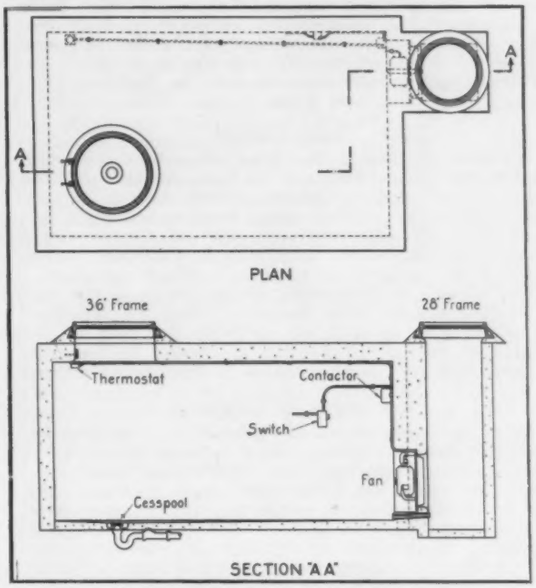


Fig. 1. One type of ventilated vault.

With a blower operated in this same vault the vault air temperature was 38 deg. C., the mean outside air temperature 15 deg. C., and the watt-hr. 2,530 so that 110 watt-hr. per hour per deg. C. was dissipated. This result indicates that with the impeller type of blower the only gain is to improve the convection action of the air. The blower assists very little if any in moving air into and out of the vault. This conclusion is confirmed by tests made by another company. In this case there was a rise of only 1 deg. C. with blower operated, but with all vents closed, and a further rise of 8 deg. C. with the blower off. With the vents open and blower operated the measured air flow was 1,015 cu.ft. per min. The air flow was not measured with vents open and blower off. The fan usually is driven by a ¼ or ⅓-hp. motor. Figure 1 shows a type of ventilated vault used by one company.

The limit of size employed for unventilated vaults appears to be about 7 x 10 ft. with height varying from 6.5 to 8 ft. The transformer capacity for such a vault varies from 50 to 150 kva., depending upon local conditions. For ventilated vaults without blowers the size is about the same, with transformer capacity from 100 to 150 kva. For larger transformer capacities fans generally are used. Up to 350 kva. the size of vaults varies with different companies from 7 x 10 ft. to 8 x 16 ft. For 600 kva. the size varies from 9 x 14 ft. to 8 x 22.5 ft.

Public Relations Section[1]

Customer Ownership*

Reports of stock sales for 1927 from member companies of the Pacific Coast Electrical Association show in some cases decreasing or no activities, compared with 1926; this no doubt is due partly to lessened construction activities on large projects and in other cases to the fact that financial frameworks were being balanced by the issuance of lower interest bearing bonds, thereby taking advantage of the very low cost of capital available over the last twelve months. For sales of stock by member companies in 1927 and since inception of plan, see Table I.

Cheap Capital

As an indication of the large amount of capital at low interest rates available to the electrical utilities, which in turn reflects the high credit ratings held by these companies at this time, the market price and yield of preferred stocks of some of the reporting member companies, as of March 9, 1928, are shown in Table II.

The advantage of securing cheap money in the case of electric utilities may be gaged from the fact that in many cases from thirty to forty per cent of the total cost of delivering electric energy to the consumers' terminals is represented by the cost of money.

Best Type of Campaign

As to the best method of conducting a sales campaign to obtain customer share holders, there is, of course, considerable variation due to the local conditions in each case. However, upon analyzing the reports received from a number of the member companies, there seem to be two well defined plans, as follows:

First—Where a company has to raise large amounts of money each year over a considerable period the continuous selling campaign appears to be the best, for the reason that it permits of utilizing a force of trained security salesmen who devote all of their time to the work, supplemented by one or two campaigns a year by the rest of the employees of the company. This arrangement permits of the funds being received by the company in steady amounts throughout the year so they can be more effectively utilized by the company, which would not be the case if the funds for the year were all received in just a few weeks.

Second—Where the amount of money to be raised during the year is comparatively small the set-up naturally does not permit of using professional security salesmen and best results are obtained by having the ordinary employees of the company carry on one or several campaigns a year. It has been rather difficult to keep up the enthusiasm of the ordinary employee for selling over a long period of time. Further, long employee campaigns interfere too greatly with the operation of the company's business.

General

On inquiry being made of member companies as to whether stockholders were being lost to any extent through the sale of their utilities securities, due to lowering interest yields, and placing their money in other securities of higher yield and less safety, the consensus of opinion is that no such losses are occuring, or if so, to such a small extent as to be negligible.

There is a basic tendency, however, which is quite noticeable with those companies where the necessity of raising capital is diminishing, or where no stock selling campaign has been carried on for a year or so, for the smaller stockholder to dispose of his holdings for various reasons. This condition, in the committee's opinion, should be given careful consideration by the industry, as a continuation of this tendency over a considerable length of time, unless offset by new sales from time to time, would ultimately disturb the primary purpose for the adoption of the customer ownership plan, namely that of obtaining and keeping diversified and scattered holders of their securities.

Those companies whose capital requirements are still large are increasing their number of stockholders, but will ultimately face a condition similar to the one cited above.

Several member companies who have had no necessity for raising additional capital through stock sales the last year or so have been enabled to keep their stockholder list fairly stable through re-sales.

[1] **S. W. Coleman**, Coast Valleys Gas and Electric Company, chairman. **Wm. Baurhyte**, Los Angeles Gas and Electric Corporation, vice-chairman. **General Electric Company**: A. G. Jones. **Pacific Gas and Electric Company**: Eugene McCann, A. F. Hockenbeamer. **San Diego Consolidated Gas and Electric Company**: Mrs. Ruth Creveling. **Southern California Edison Company**: F. L. Greenhouse. **Southern Sierras Power Company**: A. B. West.

* Report of the customer ownership committee of the Public Relations Section—F. L. Greenhouse, chairman. F. V. Boller, L. W. Jenkins, Jr., G. H. Rand, F. E. Seaver.

TABLE I—Customer Ownership Sales.

NAME	1927 New subscribers	1927 Old subscribers	1927 Total Shares Sold	1927 Par Value	Total Number Stockholders to Dec. 31, 1927	Par Value Stock sold to Dec. 31, 1927
Coast Counties Gas & Electric Co	1,179	432	8,500	$ 850,000	2,279	$ 1,665,200
California Oregon Power Company	988	560	16,265	1,626,500	3,994	4,316,900
Truckee River Power Company	135	.....	1,560	156,000	415	461,500
Elko-Lamoille Power Company	21	5	517	51,700	28	55,200
Southern California Edison Co	10,285	31,910	1,203,280	30,082,000	112,213	128,589,600
Pacific Gas and Electric Company	.....	.....	240,584	11,264,600	49,314	71,218,200
Great Western Power Company	.....	.....	8,243	824,300	12,810	16,964,300
Central Arizona Light & Power	731	128	5,941	594,100	859	594,100
San Diego Consolidated Gas & Electric Company	No Sales of Original Issue				3,254	6,292,500*
San Joaquin Light & Power Corp	No Sales of Original Issue				15,156	11,670,600*
Los Angeles Gas & Electric Corp	No Sales of Original Issue				10,651	19,394,800*
Ontario Power Company	No Sales of Original Issue				772	994,600*
Western States Gas & Electric Co	No Report				3,436	5,320,800*
Coast Valleys Gas & Electric Co	No Report				1,278	1,781,000*
*December 31, 1926						
TOTALS					216,459	$269,309,300

TABLE II—Price and Yield of Preferred Stocks, March 9, 1928.

Name	Security	Price	Yield
Los Angeles Gas & Electric Co	6% Preferred	$108.50	5.53%
San Joaquin Light & Power Corp	6% Prior Preferred	103.50	5.80%
Pacific Gas and Electric Co	6% Preferred	27.50	5.5 %
Southern California Edison Co	5½% Preferred	24.50	5.6 %
California Oregon Power Co	6% Preferred	101.00	5.9 %
Coast Counties Gas & Electric Co	6% Preferred	100.00	5.9 %

Industrial Relations*

The report of the committee for this year consists of a resumé of the educational work being done in the various public utilities of the Pacific Coast, either by the companies themselves or through employee association activities.

The subject "educational work" is open to a variety of interpretations. Generally speaking, the education of employees divides naturally into two classes:

1. Practical training in company methods and procedure through which the company benefits directly and the employee indirectly.
2. Theoretical training along broad educational lines through which the employee benefits directly and the company indirectly.

The first class of training is as old, in principle, as industry itself. It is only during comparatively recent years, however, that the old haphazard, rule-of-thumb training by individual workers on the job has given way to organized, standard training programs and the group method largely substituted for individual teaching.

The second class mentioned is the most recent departure in employee education. It has been thus far confined to those companies which have well organized, active employees' associations and has been very largely developed on the initiative of the employees themselves acting through these organizations. Although the direct benefit to the company of this class of training is open to question, the majority of employees have been quick to recognize its value in improving the general equipment of the personnel and in promoting contentment through opportunity for development. In most instances such recognition has taken the form of financial support for the educational work.

In analyzing the information submitted by the various companies contributing to this report we find both classes of educational work easily distinguishable although there is a wide variation apparent in the methods used.

The first class of educational work is divided again into two general classes, group instruction and apprenticeship or student training courses. There is a growing tendency apparent in all reporting companies toward the group method, apprenticeship or student training courses being rather surprisingly scarce.

Group instruction is carried on through actual class work, lectures and addresses, club or group meetings and contests. Three companies report classes of instruction in safety work and first aid, two of them carrying the program on through group meetings and first aid teams. One company reports a course in foremanship training which has been undertaken within the past two years and is thus far productive of excellent results. The same company reports an innovation in one of its operating divisions in the form of a complete course in divisional procedure including the proper use of all of its various accounting forms. This company also offers to its employees a course in salesmanship conducted by outside specialists. Part of the expense is borne by the company. A second company has instituted special courses designated to train employees in substation operation, conducts advanced classes in vector analysis and conducts each year, on company time and at company expense, a course on electric meters. This company also encourages the use of courses offered by established educational institutions provided that they are in line with the employee's regular duties. In such cases the company refunds one-half of the enrollment fee upon evidence of the successful completion of the course.

Some companies make use of the University of California's course in electric meters, sending their metermen to the university once a year for a short course of study.

The instruction of large groups of employees by means of lectures and addresses is reported by nearly all of the contributing companies. These lectures and addresses are sponsored by the various companies and are carried on very largely through their respective employee associations. They cover subjects pertaining to the public utility business in general and also problems of method and procedure in particular companies. In one instance instructive lectures on the electrical industry are made available to the general public and to students of local schools. Some of the subjects covered in such group meetings are: electric meters, electric appliances, various industrial applications of electricity, inter-relation of departmental functioning, specific accounting procedures, generation and distribution of electric power.

Motion pictures are employed by three companies, two of which own their own projection machines.

One company stimulates interest by means of public speaking and essay contests open to all employees. Some of the subjects of these contests are: municipal ownership, effective good-will advertising, recreational plans for employees, etc.

Organized apprenticeship or student training courses apparently exist in but three of the reporting companies. In two of the companies these courses consist of all-round training in various departments and are designed for engineering graduates. The students are picked with a view to their future value to the company and the training course is designed to give the company an opportunity to estimate their fitness for the work. They are paid a nominal salary during this trial period and are placed, in so far as practicable, on productive work. The third company has apprenticeship or cadet courses for substation and power house operators and salesmen. These men are placed immediately on productive work and are paid while learning.

In the second class of educational work three of the largest companies reporting show the most marked activity. One company has conducted successfully courses in public speaking, dramatics, elementary English, business correspondence and mathematics. This company is planning, courses in other subjects. A second company is giving financial assistance to employees who desire to improve themselves by taking courses which will serve to fit them for advancement along the lines of their work. Courses offered by established educational institutions are utilized wherever possible. In certain special cases, correspondence courses have been arranged in subjects in which a number of employees may be interested as a group. A third company has a very fully developed program carried on entirely through employee association initiative and effort. The educational work is controlled by a central committee working through sectional committees and class leaders. The courses are prepared and taught entirely by employees on their own time, examinations are given and certificates issued as evidence of successful completion. There are now considerably over a thousand graduates of these courses. The personnel department of the company is furnished with the names of these graduates for consideration in arranging transfers or promotions.

The majority of the subjects covered by all of these courses in the second class of educational work are more or less closely connnected with company activities. In many instances it is difficult to draw the line of demarcation since the successful completion of any educational course cannot fail to add to the value of an employee's services to the company.

Each company will naturally have to decide to what extent it may be advisable to support the education of employees in subjects which are not directly connected with their immediate duties.

The survey has brought out some rather surprising facts. Perhaps the most surprising thing is the apparent lack of organized effort to establish classes of instruction in the proper handling of public relations. Undoubtedly the employees of the various public utilities are well coached in the general policies existing but we believe that instruction in the specific application of these policies to individual problems could be undertaken to good advantage. There is an almost complete absence of foremanship training courses. In general the Pacific Coast seems to be slow in recognizing the value of this important phase of industrial education, being far behind the East in their methods of training foremen. There is possibly no training program which an industry could undertake which would be more productive of direct results than the training of foremen.

The evidence of the growth of educational activities which is shown by this survey is a very encouraging indication of the enlightened, progressive industrial relations policy of the coast utilities. We believe that the most successful programs will be those which work to the greatest mutual advantage of both employer and employee. It is well not to overlook the fact, however, that opportunity for self-development of any sort has a very real value to the employer in the promotion of contentment and in the development of latent ability.

* Report of industrial relations committee of the Public Relations Section—E. G. McCann, chairman.

A complete list of the courses of instruction conducted by employees' associations and by the various companies follows:

Courses of Instruction Reported by Various Contributing Companies

Courses in Established Educational Institutions

Accounting
Alternating Current Electricity
Advanced Electrical Review
Advertising
Algebra
Arithmetic
Business Investment and Finance
Direct Current Electricity
Commercial Power Sales
Diction and Vocal Technique
Elementary Hydraulics
Elementary Economic History
Essentials of Mechanics
Electric Meters (Meter Engineering)
Induction Relays
Intermediate Typing
Industrial Management
Lighting Sales
Radio
Psychology
Practical Electricity
Surveying
Trigonometry

Company Courses

Business Correspondence
Dramatics
Elementary English
Elementary Electricity
First Aid
Intermediate Stresses
Mathematics
Photography
Photographic Tinting
Public Speaking
Security Sales and Finance
Vector Analysis—Advanced

Employee Association Courses

Accounting—Elements
Accounting—Practice
Alternating Current Electricity
Arithmetic
Algebra
Business English
Commercial Electricity
Direct Current Electricity
Elements of Hydraulics
Geometry and Mensuration
Logarithms and Trigonometry
Motor Vehicles
Naturalization
Public Speaking
Steam Boilers
Steam Engines and Turbines
Switching Equipment and Power Control
Physical Education

Public Speaking*

With the idea of taking the public into the confidence of the electric power industry, progress is being made through the public speaking departments, or committees, of various utilities. A complete understanding of its problems is necessary in order that the public may equitably judge its methods of operation and by disseminating the truths and facts in this connection it is hoped that many who have in the past been suspicious, only by reason of a lack of knowledge of the facts, may be brought to realize that the power industry is the same as any other business enterprise.

Public speaking activities have been carried on along broad lines by practically all of the member companies during the past year. The plans followed have not necessarily been uniform, due to varying conditions in different localities. They have, however, all been directed toward sincere training of employees in public speaking, or encouraging the use of that talent already developed and available, or both.

Some of the companies are sponsoring associations composed of employees eager to take up public speaking under the direction of competent paid instructors. In other localities the company employees have formed associations for public speaking, instruction and practice, entirely independent of the utility company. This is, of course, an opportunity for personal advancement which readily attracts the best talent. It is interesting to note some of the most promising young men and women in the utility industry have completed training courses in one of these associations.

A consolidated report of the public speaking activities among the member companies of the P.C.E.A. for 1927 was completed and forwarded to the N.E.L.A. headquarters, for consolidation with the report of the national chairman. A copy of this report follows:

TABLE I—Public speaking committee report for California, Nevada and Arizona, year ending December 31, 1927.

Organization Classification	Number of Talks Made	Approximate Audience
1. Associations of commerce	201	23,229
2. Civic clubs	233	15,410
3. Women's clubs	28	2,582
4. Colleges and universities	8	800
5. Business colleges	3	653
6. High schools	48	9,124
7. Trade schools	3	320
8. Church groups	41	2,775
9. Conventions (other than utilities)	11	3,395
10. Farm groups	81	7,849
TOTALS	657	66,137

California-Arizona-Nevada 1927 Report to N.E.L.A.

The final figures above indicate an approximate total audience of 66,137. The three Pacific states in this geographic division have a population of something in excess of 4,000,000 people; this would indicate there is still an abundance of opportunity for expanding the efforts of the utility company along these lines.

Women's Activities*

The growth and development of the women's committee of the Public Relations Section during the past year has been most satisfactory. New groups have been formed and groups already established have done good work.

With a definite program furnished by headquarters the educational schedule has been carried out consistently. Each subcommittee has made careful study of the basic subjects pertaining to the electrical industry as represented by the individual public service company, and of current legislative measures affecting the industry.

A practical working knowledge of major electrical home servants has been gained through regular "appliance meetings" where demonstrations have been made by manufacturers' representatives, and through a systematic study of the "More Power to the Home" series published by N.E.L.A. headquarters of the women's committee.

First-aid teams have been organized in five of the groups. Widespread contact with housewives has been established through programs of various sorts sponsored by the committee. More valuable from the true public relations point of view, however, has been the slow and steady strengthening of confidence through personal contact between these hundreds of ably informed public utility women and the important miscellany of consumers with whom they meet and talk daily.

Through the whole-hearted co-operation of the California Federation of Women's Clubs, there has been effected the distribution of several hundred copies of booklets of the "More Power to the Home" series to California club women and home makers. Thus the story of electric service, written by women for women, has been carried into California homes in a form and context entirely devoid of propaganda of any sort.

The recent essay contest sponsored by the women's committee has produced a markedly increased interest in the committee. It has promoted more study and developed a more clearly defined appreciation of the aims and purposes of the committee than any effort hitherto undertaken in this section.

The co-operation between utility executives and their women's committees has been a definite factor in the success of the year just completed. Replacing an attitude of neutral tolerance, they have without exception exhibited the keenest concern and interest in the development of their committees. Local charimen, upon whose leadership and enthusiasm the success of the entire group so largely depends, have worked early and late to make their programs interesting and their accomplishments of practical value.

The women's committee now has a Pacific Coast member on two national subcommittees—Home Service, and Safety First. Through them activity along these lines will be strengthened and encouraged.

The women's committee, Public Relations Section, Pacific Coast Electrical Association, has evolved from a nebulous idea into a strong, active public relations body. It is ready to take its place with any other sectional women's committee in the United States.

* Report of public speaking committee of the Public Relations Section.

* Report of Women's Committee of the Public Relations Section—Ruth E. Creveling, chairman.

Purchasing and Stores Section[1]

Section Activities

By C. D. Weiss*

The first work of the section this year was a complete review of all studies made by the section since it was organized in 1923. The following resume shows subjects which were studied and papers published in the convention proceedings of the association.

TABLE I—Resume of Subjects on which Papers were Written and Published in the Proceedings of the Pacific Coast Electrical Association Conventions of 1923, 1924, 1925, 1927, 1928.

Accounting	1923	....	....	....	....
Budget Stores Department	....	....	1925	....	....
Devices, Material & Equipt. Handling	....	....	1925	....	....
Disbursements and Returns	1923	1924	....	....	....
Inspections and Testing of Material and Equipment	....	....	1925	....	1928
Inventories of Material and Equipment	....	....	1925	1927	....
Material Control	....	....	....	1927	1928
Ordering	1923	....	....	....	....
Obsolescence and Reclamation	....	....	....	1927	1928
Purchasing	1923	....	....	1927	....
Purchasing Department Organization	....	....	1925	....	1928
Procuring of Material and Equipment	....	....	1925	....	....
Receiving and Checking	1923	....	....	....	....
Requisition and Purchase Order, Combined	....	1924	....	....	....
Storing	1923	1924	....	....	....
Salvage, Waste and Obsolete Materials	....	1924	....	....	....
Scrap, Obsolete Material, Handling of	....	....	1925	....	....
Standardization of Materials and Equipment	....	....	1925	1927	1928
Supervision of Materials and Equipment	....	....	1925	....	....
Stationery and Printing	....	....	1925	....	....
Stores Department Organization	....	....	1925	1927	1928
Stores Department Buildings, Facilities and Material Handling Devices	....	....	....	1927	1928
Surplus Material	....	....	....	1927	1928
Zone System of Purchase Order Form	1923	....	....	....	....

The review of past work clearly indicated that the studies should be continued each year and that the following subjects should be perpetuated in order to report the latest developments of direct benefit to the purchasing and stores activities: (1) Purchasing organization and policies; (2) Material control; (3) Stores department buildings, facilities and material handling devices; (4) Surplus material; (5) Obsolescence and reclamation; (6) Inventories; (7) Stores organization; (8) Standardization and simplification of stores stocks; (9) Inspection and testing of materials.

At the suggestion of the chairman the following recommendations were adopted by the section for the guidance of future chairmen of the Purchasing and Stores Section:

1. The first duty of the chairman when taking office should be to write executive heads of all Class A member companies of the Pacific Coast Electrical Association and secure names of representatives from their companies for the ensuing year, it being understood that the previous-year members of the section remain members until changed by executive heads. (All section members must be Class B members of the Pacific Coast Electrical Association to be eligible for section membership.

2. Incoming chairman should arrange to call first meeting of section within six weeks following convention. At this meeting the schedule of meetings for the ensuing year should be prepared, naming the number of meetings, dates and places to be held.

3. Section chairman should arrange to forward copies of all meeting notices, monthly progress reports, all circular letters pertaining to section work, minutes of meetings, etc., to each member of the section, to the executive heads of all Class A member companies represented on the section, to the president and secretary and section chairmen of the Pacific Coast Electrical Association, and to the chairman of the Purchasing and Stores Section of the National Electric Light Association.

4. Section chairman should forward notice of meetings to section members at least three weeks prior to date set for meeting, together with tentative program of meeting.

5. Chairman should furnish Electrical West advance notice of meetings and reports of special activities of the section.

6. At the last session of the section preceding the convention chairman and vice-chairman of the section should be elected to act for the ensuing year, the secretary of the section to be selected by the chairman.

7. Members of the executive committee to be composed of past chairmen and chairmen of committees of the section.

Company executives object to sending too many representatives to attend parallel sessions of different sections, therefore our section desires to recommend to the officers of the association that they obtain schedules of meeting dates and places from each incoming chairman immediately following the convention, in order that officers of the association may suggest changes to avoid parallel meetings of the different sections. We believe this arrangement will insure better attendance at section meetings and avoid the necessity of too many employees of member companies being absent at the same time.

The policy of advance schedule of meetings will allow expenses of representatives to be budgeted and authorization for attendance at section meetings to be obtained in advance from respective company executives.

Many of our section members have stated from time to time that their respective organizations have been directly benefited by the discussions held at the section meetings and the development of men in their respective organizations who assist in the preparation of papers. Therefore our section urges executives of member companies to appoint representatives from their companies who will take an active part in the work of the section.

Committees reported and prepared papers on the following subjects for this year's work: (1) Purchasing Organization and Policies; (3) Stores Department Buildings, Facilities and Material Handling Devices; (4) Surplus Material; (5) Obsolescence and Reclamation; (7) Stores Organization; (8) Standardization and Simplification; (9) Inspection and Testing of Materials.

The committee on subject No. 2, Material Control, expects to complete its report and have it ready to present to the convention.

The committee on subject No. 6, Inventories, has nothing new to report this year.

At the last meeting of the section William Maddock, storekeeper, Los Angeles Gas & Electric Company, was elected chairman, and S. E. Hickman, assistant purchasing agent, San Joaquin Light & Power Corporation, Fresno, was elected vice-chairman of the Purchasing and Stores Section for 1928-1929.

Purchasing Department Organization and Policies

By J. L. Gray*

In the conduct of the business of a large or small public utility centralized buying is recognized as being the most effective and economical method of securing its materials and service, therefore calling for a well organized and efficiently conducted purchasing department, the personnel of which should be substantially as follows: purchasing agent, assistant purchasing agent, as many buyers as the business warrants, price record clerk, follow-up or tracer clerk, stenographers and typists.

Organization

This set-up may vary somewhat depending upon the extent of the work assumed by the purchasing department, but it is the feeling of this committee that the responsibility of the purchasing department does not

[1] **C. D. Weiss,** San Diego Consolidated Gas & Electric Company, chairman. **Wm. Maddock,** Los Angeles Gas and Electric Corporation, vice-chairman. **Wm. deWaard,** San Diego Consolidated Gas & Electric Company, secretary. **Coast Counties Gas & Electric Company:** M. F. Wales. **Flagstaff Electric Light Company:** I. F. Veazy. **Great Western Power Company:** F. R. Sherwood, F. W. Smith. **Los Angeles Gas and Electric Corporation:** Wm. Maddock. **Nevada Valleys Power Company:** A. D. Henderson. **Pacific Gas and Electric Company:** J. H. Hunt, A. A. Charonnat. **Southern Arizona Power Company:** V. P. Ure. **San Diego Consolidated Gas & Electric Company:** S. R. Robinson. **San Jonquin Light & Power Corporation:** D. P. Mason, S. E. Hickman. **Southern California Edison Company:** W. J. McCullough, H. O. McKee, R. B. Guilbault, F. F. Henry, H. N. Sessions, E. F. Watkins, J. L. Gray. **The Southern Sierras Power Company:** C. A. Kelley, C. B. Lore. **Truckee River Power Company:** H. P. Dayton. **Tuscon Gas, Electric Light & Power Company:** L. H. Prentiss.

* Report of section chairman.

* Report of committee of Purchasing and Stores Section—J. L. Gray, chairman. S. E. Hickman, S. R. Robinson.

cease until the goods purchased have been received, checked in and found to be as ordered. This responsibility would, therefore, call for a more elaborate set-up than outlined above and the detail would also depend upon the size of the utility of which the purchasing organization is a part; but in the event that all responsibility for the purchasing and delivery of goods is assumed, the personnel and duties of the purchasing department would be substantially as follows:

Purchasing Agent—To exercise general supervision over his department, formulate policies, negotiate upon large orders and contracts, and represent his department with other department heads.

Assistant Purchasing Agent—To assist the purchasing agent in every way possible and handle the detail of the department, reporting to the purchasing agent.

Chief Clerk or Buyer—To handle requisitions received by the department, allocate them to the several buyers, send out requests for bids on special work—reporting to the purchasing agent or the assistant purchasing agent.

Buyers—To handle all requisitions and matters assigned to them in the most effective manner.

Follow-up or Tracer Clerk—To keep in touch with all orders placed and see that goods covered thereby are delivered as agreed.

Price Clerk—To keep a complete record of prices quoted and check invoices against prices shown on orders. (It is the practice of some utilities to have invoices checked for prices by the auditing department, but we believe this checking is properly the function of the purchasing department, as that department is more familiar with the conditions and better prepared to secure adjustments of incorrect prices charged.)

Invoice Claims or Adjustment Clerk—The checking of invoices would necessarily call for the making of claims or adjustments of incorrect invoices or goods received, thereby making it necessary to have someone responsible for making these claims or adjustments. These duties could be consolidated under one head, say the invoice claims or adjustment clerk.

File Clerk—To have supervision and be responsible for filing of all orders and correspondence of the department, catalogs, etc.

The above outline would call for stenographers and typists, the number depending upon the volume of work of that nature to be done. There are, of course, other duties to be arranged for but the detail would depend upon the volume of work done by the particular purchasing department.

Policies

This is a subject which is very important and should not be considered lightly, as the purchasing department is the contact point of a public utility with the selling public and a good or bad impression may be gained by the public at large from that point of contact. As the company is in the business of selling an intangible commodity—service—and must have the good-will of the public with whom it deals, this good-will which is necessary to the sales end of the organization can and should be strongly supported by the buying end of the organization by being fair and just in all its dealings and still be firm, courteous, and businesslike in its contact with the selling public, and many an alleged grievance can be dissipated by the diplomatic handling of the business of the purchasing department, as its reputation for courtesy, honesty and fair dealing will go abroad and be considered by the selling world as well as the public at large.

Goods and service should not be purchased upon the basis of price alone, but upon the reliability, responsibility and integrity of the seller as well, and many embarrassing situations may be saved to the utility if these points are carefully considered before placing the order.

Marchandise Manufactured at Home—Another point of policy to be seriously considered is the policy of buying merchandise manufactured at home, particularly goods manufactured or carried in stock by manufacturers or merchants upon whom the success of the serving utility depends. Prosperity must begin at home and in order to contribute to the desired home prosperity, local institutions should have first consideration, and many a manufacturing or selling concern has been able to exist and forge ahead by the support, moral and physical, given them by the communities in which they operate.

Load Building—This policy may be particularly dwelt upon at this time due to the earnest effort and desire of all public utilities, particularly those engaged in the sale of electricity to build up a load for their particular organizations.

New Business—In connection with this phase of policy the purchasing department can lend material assistance to the sales department of a utility by cooperating with the sales department in securing business by so placing its orders for materials that business desired may be attracted by the diplomacy of the personnel of the purchasing department. Every man should be worthy of his hire and every vendor is en-

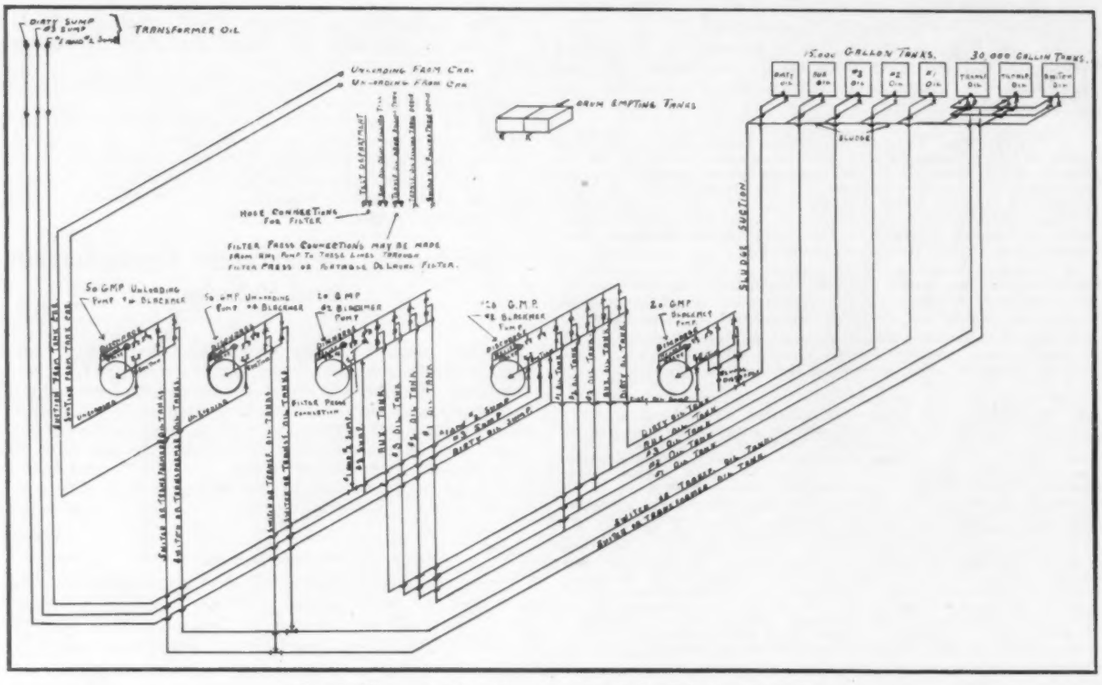

TRANSFORMER OIL
UNLOADING FROM CAR
UNLOADING FROM CAR
DRUM EMPTYING TANKS
HOSE CONNECTIONS FOR FILTER
FILTER PRESS CONNECTIONS MAY BE MADE FROM ANY PUMP TO THESE LINES THROUGH FILTER PRESS OR METHODS OF LOCAL FILTER.
15,000 GALLON TANKS.
30,000 GALLON TANKS.
SUCTION
DISCHARGE

Fig. 1. Diagram of transformer and switch oil handling system.

titled to just consideration by the buyer, and when the seller has been made to feel that the purchasing department is conducted without bias or prejudice toward him, he will make his convictions known to others of his fraternity and thereby create a friendly feeling for that particular utility by the public at large.

Good-will—Purchasing departments of all public utilities are fast becoming recognized, not as necessary evils, but as the medium of speading the gospel of "honesty, fair dealing, and courteous treatment," which has been the slogan of one of the largest public utilities of the West for mare than 20 years, thereby materially contributing to the success of the particular public utility of which they are a part.

Stores Department Buildings, Facilities and Material Handling Devices

By William Maddock*

This committee was organized during 1926-1927 to make a thorough study of the subject named and keep it up to date so that each company might obtain full benefit from the operations of the various companies. The 1926-27 committee handled the entire subject in a general way, specifying a model plan to meet the needs of a modern stores department. The present committee thinks it advisable to describe some of the facilities in detail, and particularly recommends that the new operations devised be brought before the section for discussion and that the results be published for the benefit of our industtry.

It was therefore decided to describe in this year's report the details of oil storage and oil filtering, and the subject of storeroom and storeyard illumination, and details of warehouse bin construction.

* Report of committee of Purchasing and Stores Section—William Maddock, chairman. William deWaard, H. O. McKee.

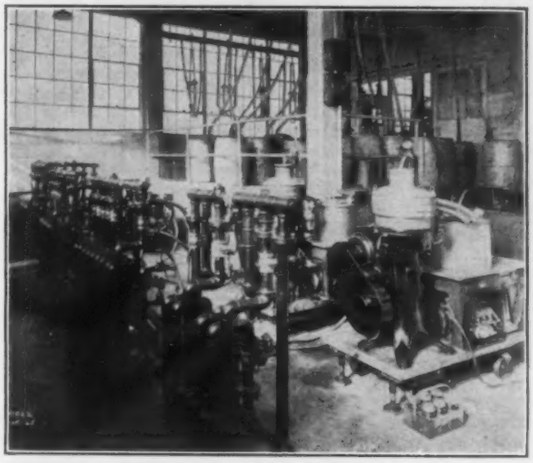


Fig. 2. Interior of oil room. Note headers.

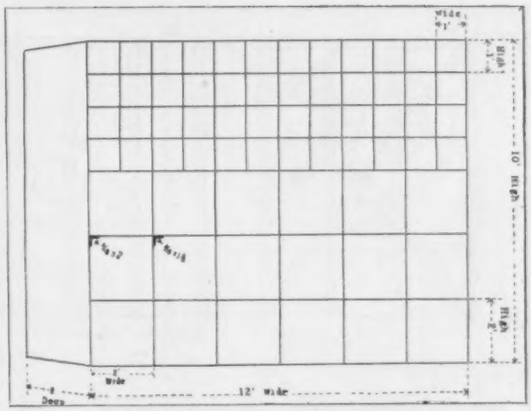


Fig. 3. Front view of steel bin section.

Oil Storage

The system described is the one used by the Southern California Edison Company at its Alhambra general store. It is accompanied by a print showing the system of piping and a photograph of the plant.

The storage capacity consists of three 30,000-gal. tanks and five 15,000-gal. tanks. The oil house has a floor space of 100 x 40 ft. and is divided into two sections. One section is used entirely for the storage of oil drums ready for shipment upon request. The other section is used for testing, filtering and distribution.

Headers and Piping—An elaborate system of headers is employed to handle the transformer and switch oil, as shown in Fig. 1 on proceeding page.

This apparently complicated, but very simple, system of headers is necessary for the proper testing, filtering and distribution of the various oils. Oil can be directly pumped from the tank cars within the plant to any of the storage tanks. A system of piping is used which enables old transformer and switch oil, which has been

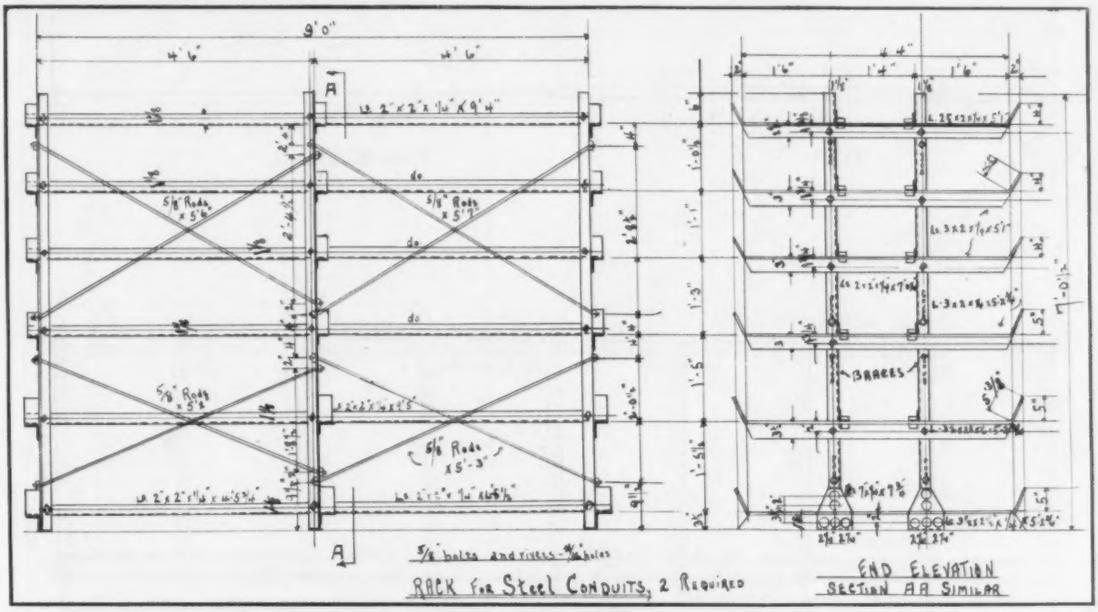


Fig. 4. Storage rack for pipe conduit, long-handled tools, wooden moulding and other long material.

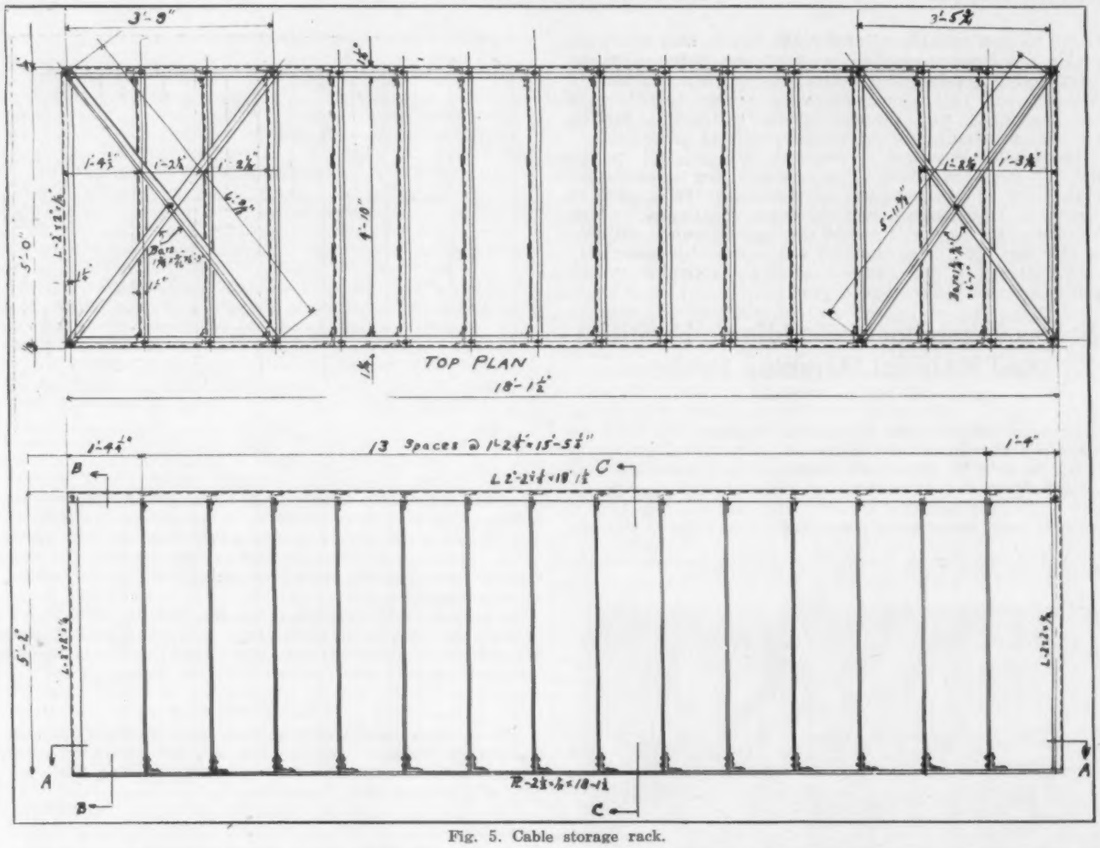


Fig. 5. Cable storage rack.

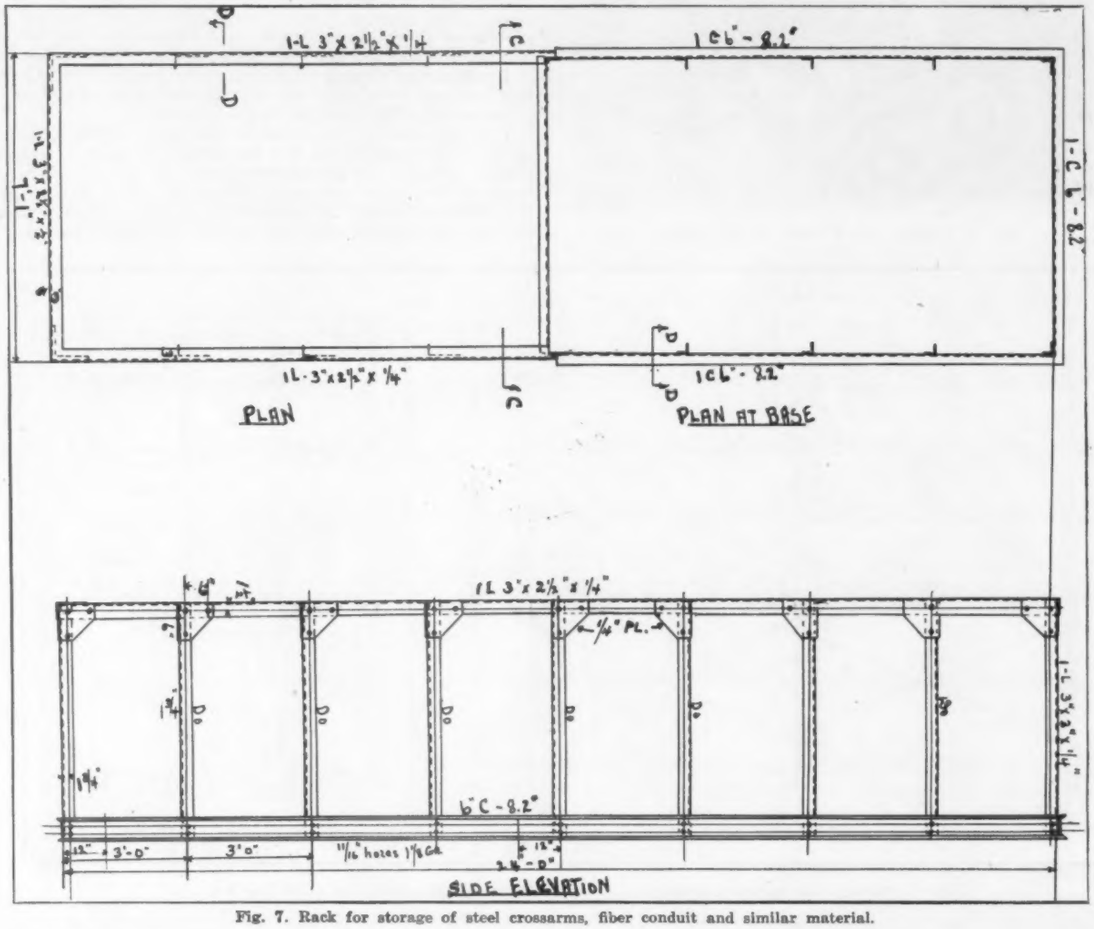


Fig. 7. Rack for storage of steel crossarms, fiber conduit and similar material.

returned for reclamation, to be conveniently and efficiently filtered, purified and stored. The installation of pipe lines from the oil filtering plant to the transformer testing department is arranged so that large station transformers can be filled there, and, when occasion demands, the circulation of hot oil can be easily accomplished. This is essential as, on certain classes of transformer dry-outs, it is desirable to circulate the hot oil.

All oil is entirely controlled from the five headers shown in Fig. 2, and by means of a system of valves, pumps, tanks and hose connections it is readily transferred and purified. The purification of the oil is accomplished by two centrifugal purifiers and one 12-in. filter press.

Drying Oil Drums—The oil drums which need drying are dried by means of hot air obtained from two standard motor-driven air driers which are permanently connected and can readily direct the hot air to the drums.

It is desirable to keep the temperature of the room as high as practicable to reduce the length of time for effective drying. Wherever possible the pipes used for conducting the hot air are insulated to cut radiation losses to a minimum.

An electric oven is provided to dry thoroughly the blotters used in the filter press. After all drums are thoroughly dried, they are transferred for filling to the four 50-gal. measuring tanks, equipped with overflows. This method of filling drums is both rapid and accurate and there is practically no waste of oil in this procedure.

Purifying—Two 400-gal. storage tanks, located near the five headers, are also used in the process of purifying small quantities of oil.

Loading and Delivering—One entire section of the oil house has a platform of such height as to allow the oil drums to be moved conveniently to and from the trucks used for taking the oil to the various districts and substations. The delivery of some of the transformer and switch oil to various points on the system also is done by means of trucks equipped with tanks. This method is considerably more efficient where oil is used in larger quantities.

Meters—Another feature of the oil house is the installation of an oil flow meter in each of the main headers which makes it possible to obtain an accurate check of the quantity of oil in each of the various storage tanks. By a simple piping and valve arrangement, these meters will indicate accurately the amount of oil that is added to or taken from the storage tanks.

Testing—All oil before shipment is tested and reported upon suitable forms. The oil testing equipment is situated convenient to the main headers, and also to the storage platform, so that oil tests can be made readily at any time from any of the tanks or while the oil is being circulated.

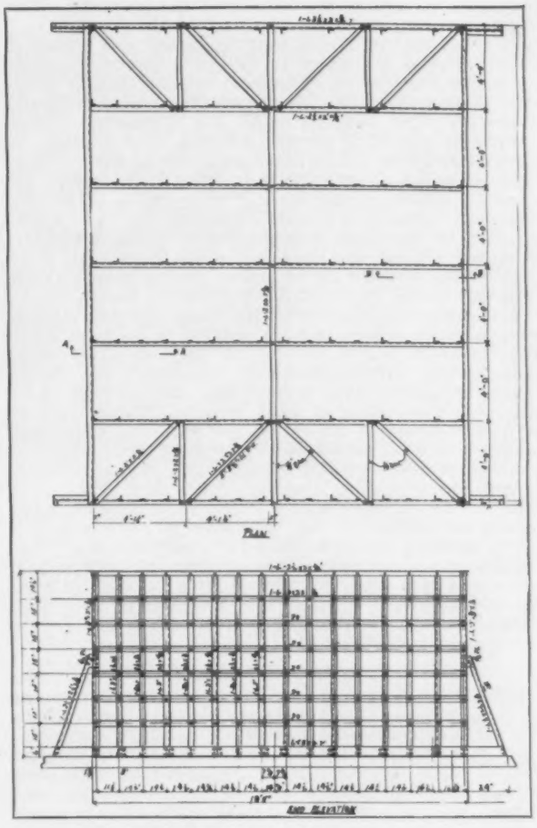


Fig. 6. Steel and iron storage rack.

Illumination of Yards and Warehouses

Yard Lighting—When designing a lighting system for a storage yard, care must be exercised to make the installation both ornamental and useful, and a well designed standard should be selected for the lights surrounding the yard. These standards should be spaced about 200 ft. apart and should be about 14 ft. high, using a 200-watt incandescent lamp. With a lighting system of this description surrounding the yard, the watchman can observe all movements of the trucks in the vicinity of the yard and can watch everything of a

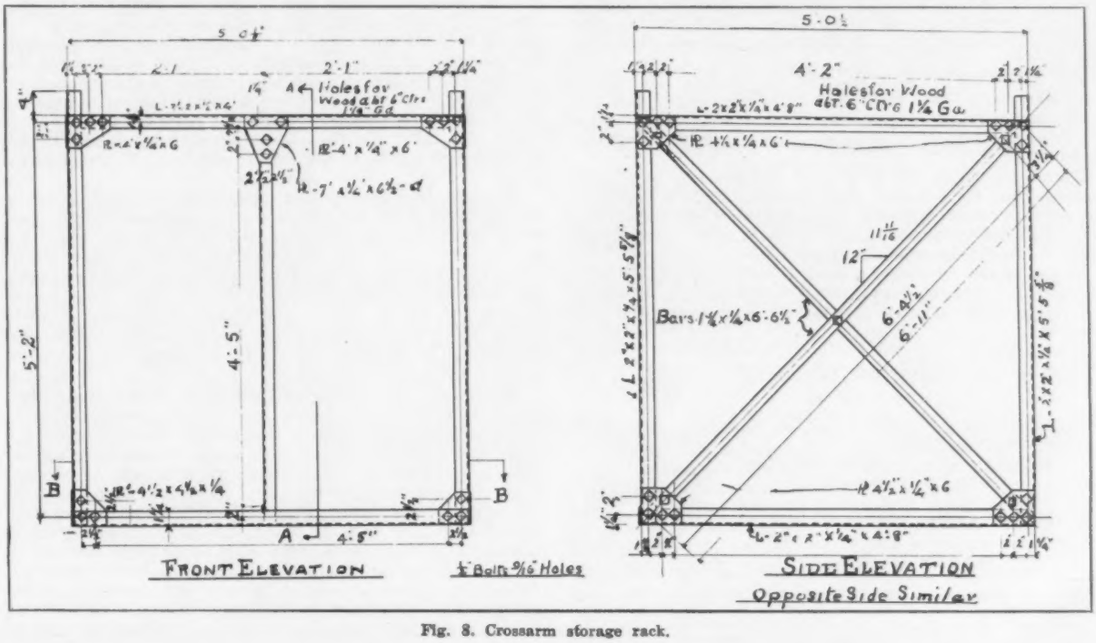


Fig. 8. Crossarm storage rack.

suspicious nature on the outside of the property. The lighting posts can be made a part of the fence.

In order that materials may be loaded and unloaded at night, it is necessary to design a lighting system to facilitate this work. The flood lights should be portable so that they can be moved from place to place where the work happens to be, and a system of plug receptacles should be placed so that a floodlight can be plugged into them. The best unit is one of the pedestal type which can be revolved so that it can be focused on a certain area where the work is in progress. It is very important that enough light is available for night work, as accidents are much more numerous at night and the increased cost of the light is a small item. All electrical conductors should be placed underground to keep them out of the way of traveling cranes, booms, etc.

Warehouse Lighting—For the main lighting system we are chiefly interested in getting a uniform light over the entire warehouse and the units should be close to the ceiling and equipped with reflectors The ceiling should be divided into squares and the lighting units placed in the center of each square. These squares should be about 12 ft. on the side and each unit equipped with one 200-watt incandescent light.

A system of drop-lighting should be installed between each tier of bins, using a protected 100-watt light. This light can be equipped with movable reflector and guard so that the entire light can be thrown into the bins.

The switches should be placed in convenient locations. The number of switches will be governed by local wiring ordinances according to the capacity of the circuits, but they should be wired so that a portion of the entire warehouse lights will be turned on when the first switch at the door is operated.

Bins, Shelving and Storage Racks

Bins—Steel is the most economical material to use in bin construction. The bin shown in Fig. 3 is one which is capable of storing the majority of standard materials. The larger sections are 24 in. square and the smaller sections 12 in. square. They are placed back to back and arranged at right angles to the doors and platforms. Specially constructed ladders are used to reach materials in the upper sections. The bins are painted an olive green and stenciled with white paint showing material contained.

Storage Racks—Fig. 4 shows in detail the construction of a rack suitable for storing conduit pipe, long handled tools, pike poles, wood molding, etc.; in fact, all long material which it is inconvenient to stack. The rack is built of angle iron and larger openings are provided at the bottom, the openings being smaller as the rack is built up. The sketch shows all measurements.

Fig. 5 shows in detail a rack suitable for storing the short pieces of lead cable, varnished cambric cable or rubber covered cable. These are usually in rolls about 50 ft. to 150 ft. long. The rolls are stored in the openings and it is convenient to find a specified length; it is not necessary to be continually breaking down the pile to find a certain piece. All measurements are shown on the sketch.

Fig. 6 shows in detail a rack for storing tool steel, mild bars, etc. This rack is built of angle iron and the sections are 15 in. square. Care should be taken when designing this rack to use steel capable of carrying the entire load.

Fig. 7 shows in detail a rack for storing guy wire boxing, steel cross-arms, fiber conduit, etc. It can also be used to store conduit pipe, but vertical racks are probably better for storing large stocks of conduit pipe, as they take up less space.

Fig. 8 shows in detail a rack to store 7-ft. and 9-ft. cross-arms, and is very useful in a substore where cross-arms are issued to the light crews over the counters.

Surplus Material

By William deWaard*

The necessity of maintaining an adequate supply of material for construction and maintenance purposes tends to create the problem of surplus material.

If the working capital invested in material and supplies is to be kept at a minimum and operating costs reduced, this problem must be controlled effectively.

For the past three years the subject of surplus material has demanded special attention. Major construction programs have been completed and the expansion of the Pacific Coast public utility plants has reached a point where they are well in advance of the requirements of their fast-growing communities. During this period of tremendous growth and due to the improvements in operating equipment and construction methods, the majority of public utilities accumulated a considerable quantity of surplus equipment and material. In some cases this surplus stock was from 20 per cent to 40 per cent of the total amount invested in material and supplies.

Classification and Causes

Surplus material may be classified as follows:

(a) Obsolete material.
(b) Excessive material.

Under the classification of obsolete, we should consider all equipment and material which cannot be used in its present form, or cannot be made into material acceptable as a substitute, and which is not required for stand-by service.

As excessive material should be classed standard material of which there is a supply in excess of requirements, sufficient for a three-months period. This should not include insurance or stand-by service equipment, or parts.

The principal causes of the accumulation of surplus material are:

1. Changes in equipment, due to improvement in sciences.
2. Changes in construction specifications.
3. Equipment and material left over from construction work (salvaged material).
4. Errors in ordering material.
5. Late arrival of material ordered for specific construction work.
6. Cancellation of proposed work for which material had been ordered.
7. Incorrect estimating.

Corrective Measures

While it is not within the power of the stores department to eliminate all the causes mentioned, it is recommended that the following corrective measures be adopted to prevent the accumulation of surplus stocks:

Changes in Equipment Due to Improvement in Sciences—Establish close co-operation between the various departments and the stores department. This particularly refers to the engineering department, which should advise the stores department as far as possible in advance of contemplated improvements in equipment. The sales department can then be notified and will have an opportunity to see if a market may be found for the equipment to be retired and also the repair parts carried in stock therefor. When making estimates for the changes in equipment, the engineering department should, wherever possible, give specific information as to the probable future use of the equipment to be retired. If such equipment is to remain in stock for future use, the cost of the repairs necessary for placing the equipment in good condition should be charged to the account which derived the benefit of its use before retirement. Past experience proves that such equipment should be placed in stock at a highly depreciated value, if, later on, the stores department is not to be penalized when it is decided to dispose of this equipment.

Changes in Construction Specifications—Establish a definite and fixed routine before construction and material specifications are changed. This should give the stores department an opportunity to reduce the stock of material about to be declared obsolete and to cancel any orders for such material which may have been placed. In cases where operating efficiencies greatly offset any losses which might occur in the stores department, the old material should be disposed of as soon as the replacing material arrives.

Equipment and Material Left Over From Construction Work—This is almost beyond the control of the stores department, except that requisitions for equipment and material should be closely scrutinized before material is ordered. Used equipment should be placed in stock at reduced value.

Errors in Ordering Material—All requisitions for material should pass through the stores department, in order that the storekeeper may check them and have an opportunity to attempt substitution from material already on hand. Careful perusal of requisitions is particularly important in instances where "high pres-

* Report of committee of Purchasing and Stores Section—William deWaard, chairman. D. P. Mason, H. N. Sessions, F. W. Smith.

sure" salesmen have persuaded plant superintendents and foremen to order non-standard material.

The operating department executives should be made to understand that the ordering of multiple sets of stand-by repair parts is wasteful. Often one or two sets are sufficient and parts may be reordered any time after the first or second sets have been used. This refers particularly to turbine and motor bearings, armature and motor coils, compressor and pump repair parts, repairs for switches and transformers, special valves, and others.

It is recommended that when placing requisitions for special material on the purchasing agent, a large stamp be used, marked "Special Item," thus drawing the attention of the general manager and general superintendent to the requests for the purchase of such items and affording them opportunity to investigate the need of this equipment, before approving the purchase.

It is further recommended that requisition on the purchasing department covering material ordered for trial only be indicated by marking with a large stamp, "Trial Order," not only to call the attention of the executives to the ordering of such material, but also to notify stock card clerks, the receiving clerk and order clerk, that such material cannot be reordered until report is received from the person who requested the placing of the requisition, giving his approval and recommendation. Upon receipt of this material it should be delivered immediately to the department requesting the purchase and should be charged out.

Late Arrival of Material for Specific Construction Work—The construction and maintenance work should be budgeted and scheduled in advance, which enables the stores department to arrange for the arrival of the necessary material as close as practical to the time when required.

Cancellation of Proposed Work—Careful planning and budgeting will minimize this phase. The engineering department should notify the stores department immediately of the changes and cancellations of scheduled work, thereby giving them an opportunity to cancel the deliveries of material ordered for such work, or to use the material already received for other jobs.

Incorrect Estimating—The stores department can assist in reducing recurrences of such cases by reporting to the engineering department the losses incurred.

General

It is recommended that the executives be furnished graphs or charts, showing each month the capital invested in material and supplies, amounts of material purchased and issued and also the stores department operating expenses. To secure their co-operation in disposing of surplus material, the executives should be furnished annually with a detailed statement of surplus material which has not been disposed of.

It is recommended that in each organization a surplus material committee be established, consisting of the plant superintendents and the storekeeper, to determine what equipment should be disposed of. In cases of difference of opinion, the decision of the man in whose department the material in question is generally used should be the determining factor.

Disposition

In considering the disposal of surplus material, the first thing of importance is the relative value of the item. Time should not be spent on articles for which there is no market and in instances where the cost of selling would be prohibitive, such material should be scrapped.

It is recommended that a sales department be established to handle the sale of all surplus material. In the smaller companies, where such expense may not be warranted the purchasing department should take care of this work.

Standard material in excess of two years' requirements should, if possible, be returned to the original vendors, at prices not less than 20 per cent of original cost. In some cases articles which have become non-standard with a company, but standard elsewhere, may be returned to the vendor at cost and exchanged for material of the same class, of standard sizes; for instance, exchanging of non-standard fuses, bolts, screws, charts, etc.

The establishment of a central clearing house by Pacific Coast utility companies for the disposition of surplus material does not seem advisable, because this problem is principally a question of salesmanship, and concentrated and continued effort by the stores and sales departments. The expense of this work can better be absorbed by the individual companies, instead of giving periodical financial support toward the maintenance of a central bureau. However, it is felt that results may be obtained by the interchange of surplus material lists by member companies, in order that their respective purchasing departments will have an opportunity to buy such material, if needed, at reduced prices.

It might be timely in this connection to describe the method used by one of the California public utility companies to reduce its surplus stock. About three years ago this company had an investment in its material and supply account of $645,000, a considerable portion of which was tied up in obsolete and excessive material. Various attempts had been made to reduce the inventory, with indifferent results, through the medium of material committees and through sales. The following method, however, brought the desired results:

The storekeeper took a copy of the last annual inventory, in which all material carried in the material and supply account is listed in the same sequence as the stock card record. The stock card record, showing the past history of all material on hand, was then carefully gone over by the storekeeper, who marked on the annual inventory any items which he knew were positively obsolete, or excessive, or questionable. After considering each class of material he would interview the superintendent of the department interested and it was immediately decided under which of the following divisions the items in question were to be classed:

Division 1. Obsolete—Material which was no longer standard; not acceptable as a substitute, or not required for stand-by service. Sold immediately for scrap.

Division 2. Substitute Material—Non-standard material which would be acceptable as a substitute. Such material to be disbursed before standard material was issued.

Division 3. Salable—New non-standard material, usable by other firms, which was to be sold at cost, less 20 per cent.

Division 4. Excessive—Standard material of which they had more than a two years' supply and which was to be returned to manufacturers, or sold.

This method had the advantage of making it unnecessary to prepare lengthy statements and placed the responsibility where it belonged. Of course, it is readily seen that the storekeeper must be thoroughly familiar with the stock on hand, its purposes and past history, and also must possess a knowledge of the company's property.

In connection with the foregoing, the utility company states that its investment in the material and supply account for the past twelve months has been held between $341,000 and $420,000, with an average turnover of $205,000 per month during the same period, and that at no time has it been found necessary actually to scrap any material or equipment.

Your committee wishes to emphasize the fact that a storekeeper's thorough knowledge of his company's property and equipment, and his individual and untiring efforts are the most essential factors in solving the problem of surplus material.

Obsolescence and Reclamation

By W. J. McCullough*

This committee has found that there are certain practices in the handling of obsolete material and in reclamation work which, if followed carefully, will result not only in considerable saving, but in more efficient methods. In the purchasing and stores department lies the responsibility for the proper ordering of materials to be kept as stock items, for the functioning of a materials committee to whom all materials and equipment are submitted for final disposition, and for the proper operation of a reclamation program which will be thorough and efficient.

Obsolescence

In the operation of a public utility, a certain amount of scrap metal, broken tools, worn out machinery and equipment will be returned to headquarters for disposal, and various kinds of material and equipment will be retired due to obsolescence. The committee is of the opinion that it is the duty of the Purchasing and Stores Section to follow up the receipt of such materials and equipment and arrange for disposal at the earliest possible moment. Such materials and equipment returned

* Report of committee of Purchasing and Stores Section—W. J. McCullough, chairman. F. F. Henry, C. B. Lore.

to stores because of obsolescene obviously becomes more obsolete and more out-of-date until disposed of. The committee finds upon investigation that 95 per cent or more of equipment used by public utilities is purchased in a manufactured state. Materials in a raw state, that is, before being worked up into a particular article, seldom become obsolete. For example, sheet copper is used for manufacturing insulator fog protectors. If the fog protectors are found to be of no use they are declared obsolete and sold as scrap, although the sheet copper in stock for the manufacture of this item is standard and may be put to other uses.

Material Committee

This committee recommends the appointment of a material committee in each of the member companies to whom all materials and equipment shall be referred for final disposition. This material committee should be furnished with typewritten lists of items that are to be considered showing the quantity on hand, the correct description, cost, and station or store from which returned. This committee should be represented by all departments ordering, purchasing and using materials and equipment, thus keeping all departments advised of losses due to obsolescence.

Ordering Material

The purchasing and stores organization should be leaders in advancing the thought that the most thorough investigation and careful consideration be given to items which are ordered for stock before being adopted as standard. This will undoubtedly have a tendency to reduce the number of items being returned to headquarters because of obsolescence.

The committee recommends constant attention and close supervision of the purchasing and stores forces by ordering consistently and in accordance with the requirements, and by seeing that all items in the department are well cared for.

The using department should understand that it is not only charged with the usable materials that are actually delivered but, as a matter of fact, is ultimately charged, through inventory adjustment, for depreciation due to deterioration or obsolescence.

Reclamation

The reclamation of materials and equipment should start at the point where used, and thus avoid damage by loading on trucks or cars, and so save back hauls and unnecessary handling. All employees regardless of the position they occupy should be informed from time to time of the cost of materials and equipment, and the committee is of the opinion that this information will tend to make them more interested, as well as more careful, in the handling and use of such materials and equipment.

The department handling the reclamation work should see that the company gets every penny's worth of service out of tools or equipment purchased, and must not permit articles to be turned in as scrap until they have performed their full service. To correct any troubles of this nature, it is suggested that individual cases be reported to the department heads with request that they issue such instructions to the users as will prevent a recurrence.

Only such items should be reclaimed as would otherwise have to be purchased. The force engaged in reclamation work should be steadily employed—handy men properly broken in on this class of work soon become expert; they are employed at a cheaper rate and are satisfied with the class of work, whereas skilled men will not be. The reclamation plants should be located at central points on the system and in connection with the stores department. Reclaimed materials must be as good as new in every way, including appearance. The success or failure of the reclamation department will be governed by this one feature to a large extent.

Classification

Tools returned may conveniently be classed as follows:

1. All scrap tools to be indicated by red inspection tag stating defect, and the card signed by the foreman or tool inspector.
2. All bad order tools to be indicated by a blue tag stating defect and signed by foreman or tool inspector.
3. All good tools to be indicated by white tag for the reason that quite often construction gangs will turn in tools which, while usable, are really in need of repairs, and should be put through the reclamation shop before being returned to service.
4. All tools tagged with white inspection card, indicating they are in usable condition, should be jointly inspected upon receipt at headquarters by the salvage storekeeper and section storekeeper in charge of tools; the white inspection card should be signed by the foreman or tool inspector.

The question as to what constitutes reclaimed materials has been classified into three divisions by some very competent authorities:

1. Materials sorted from scrap which require no labor to make serviceable should be known as "recovered."
2. Materials sorted from scrap which require labor to make serviceable should be known as "reclaimed."
3. Materials, tools or equipment, returned because of defects or worn parts, should be known as "repairs."

Obviously labor cannot be reclaimed and no money should be spent on reclaiming materials or equipment that cannot be used, or for which the company has no immediate use. Experience has demonstrated that materials cannot, as a rule, be reclaimed and disposed of by sale to outsiders at a saving in price over the "as is" condition.

Costs are necessary, although elaborate cost records are not recommended. A competent foreman in the reclamation of materials and equipment should get costs on items when first reclaimed, and he will know whether the expense is justified. The committee is of the opinion that an elaborate cost system will retard rather than advance the work of the reclamation department.

Stores Department Organization

By A. A. Charonnat*

In the utility industries many forms of organization of the stores and accounting departments are found.

The independent operation of the stores department naturally develops the accounting and physical control that is most effective. As a rule, when stores activities are operated independently the company's materials are better protected, standardized, accounted for and supervised.

Activities

The functions of the stores department embrace two activities:

(a) Stores accounting.

(b) Storekeeping.

The stores accounting department should be responsible for accounting for materials and supplies received, on hand, and issued. It should check vendor's invoices against copies of the purchase orders to eliminate duplicate invoices and to verify the authority for billing; it should check materials received with the invoices for quantities and specifications, and should keep such stock ledger accounts as may be required by the size of the company and the diversity of its activities.

The storekeeping or warehousing department should be responsible for the proper storage and protection of material, supplies, and equipment. It should receive and tally all shipments of materials, be responsible for verifying the specifications with the purchase orders, and make such other reports as may be required by the accounting department.

Organization

The stores department should be so organized:

1. That there would be a general stores department with storekeepers and warehouses at convenient locations.
2. That the general storekeeper should report directly to an executive officer of the company.
3. That the local storekeepers should be so placed in the local organizations that they do not report to a supervisor responsible for the use of the materials.
4. That the general storekeeper should use traveling storekeepers to make effective his supervision over the local storekeepers and storeroom.

* Report of committee of Purchasing and Stores Section—A. A. Charonnat, chairman. F. R. Sherwood.

Standardization and Simplification of Stores Stocks

By C. A. Kelley*

Standardization and simplification of stores' stocks is one of the greatest aids, if not the best aid to material control and the reduction of investment in material and supplies.

Undoubtedly much of the construction performed by

* Report of committee of Purchasing and Stores Section—C. A. Kelley, chairman. D. P. Mason, H. O. McKee.

central stations may be accomplished through the use of two or more different kinds of appliances, equipment or apparatus. These various items may be equally good and efficient, but to carry more than one kind in stock means a duplication which calls for two or more times the investment and the necessary storage space in the storeroom.

Selection of Standard

Opinion will probably differ among the members of the organization as to which item is better for a particular purpose, and hence it would seem advisable, as recommended last year, that the choice between various appliances offered be made by a committee composed of a representative of each department interested.

SOUTHERN CALIFORNIA EDISON COMPANY
STORES DEPARTMENT

No.....
....., 192....

Application for following material to be adopted as a STANDARD STOCK ITEM for use of Southern California Edison Company

1—Detailed description Material:

2—No. Blue Print or Sketch: 3—Approximate monthly consumption:

4—Quantity to be purchased: 5—Approximate unit cost:

6—Can be purchased from or manufactured by:

7—Purpose for which to be used:

8—New Stock: or used in lieu of:

9—Disposition of Old Stock:

10—Additional Information:

.....
.....
.....
Department

APPROVED:
No.....

Fig. 1. A form used in recommending changes in standard stock items or the adoption of new standard items.

When an item has been decided upon by this committee it should be made the standard and should be carried in stock by the stores department at all times in quantities sufficient to meet the demands of the organization.

SOUTHERN CALIFORNIA EDISON COMPANY
STORES DEPARTMENT

....., 192....

STOCKBOOK AND STANDARD LIST ADDITIONS AND CORRECTIONS

Add to Section.....the following item:
.....
.....
.....
.....
The description of material now carried in Section .....as follows:
.....
.....
.....
.....
Should be changed to read:
.....
.....
.....
.....
Units of measure.....
Purpose .....
Used in lieu of.....
Authority .....
The above changes have been made in General Store Stockbooks.....
The above changes have been made in General Store Ledgers.....
Th above changes have been sent out to holders of Std. Lists.....
Approved: .....
Storekeeper
.....
Asst. Gen. Storekeeper
.....
General Storekeeper
Signed:.....
Master Stockman
C.C. to Section.....

Fig. 2. A form used in notifying all parties concerned that changes have been made in standard stock items.

Change of Standard

No other appliance for that purpose should be purchased or stocked until the committee mentioned above has authorized the change of standard. Anyone desiring this change of standard should prepare an application along the lines of the form shown in Fig. 1, now in use by one of the member companies. This application having been approved by the department head should be forwarded to the committee for consideration.

If the change in standard is approved, the stores department will make the necessary requisitions on the purchasing department for the material and dispose of the substituted items as directed by the committee. The change having been made, a form such as shown in Fig. 2 is suggested as a means of notifying all parties concerned relative to the change and also as a means of seeing that the change has been fully and correctly consummated.

Inspection and Testing of Materials and Equipment

By R. V. Dodge, Jr.*

For some time the opinion of members of the Purchasing and Stores Section has been that there is need for a committee to deal with problems involved in the inspection and testing of materials and equipment. It is believed that certain phases of this work rightfully come under the scope of activities of this section without encroachment upon the premises of the technical section to which the subjects have been assigned.

Previous Report

Reviewing previous efforts along these lines, we find in the proceedings of the Pacific Coast Electrical Association's ninth annual convention in 1925, the report of a subcommittee of this section, advocating thorough and practical systems of inspection of material and equipment.

Advantages of Inspection

Among the advantages to be derived from such systems may be mentioned the following:

1. Prompt adjustments with the manufacturers for defective material and shortages and with the carriers for damage in transit.
2. Savings in cost of premature renewals occasioned by the use of inferior or defective materials.
3. General reliability and increase in the factor of safety.
4. Elimination of dependence upon trade-marked brands which have heretofore been considered standard, thereby discouraging attempts by unscrupulous concerns to unload material of impaired quality.
5. Determination of the most suitable quality, resulting in maximum economy in purchasing. In other words, definition of a standard quality which is good enough but not too good for the purpose.

Physical Tests by Receiving Department

Now, the bulk of superficial inspection work naturally falls to the lot of the receiving department as it is this department which is generally held responsible for the checking of the material received against the purchase order. In addition to the copies of the purchase orders, this department should be furnished with copies of the specifications applicable to the material ordered. It is also important to furnish the necessary equipment to check efficiently and accurately the incoming shipments. Various modern measuring devices should be included in order correctly to check and tally the lengths, weights, counts, diameters, etc., from which claims for shortages and inaccuracies may be filled. In many cases, it is advisable to supply gages to facilitate the determination of suitability. For example, gages may be effectively used in checking the sizes of locust cross-arm pins, also in checking the diameters of holes in manufactured cross-arms. Gages also may be used on threads, on bolts and on other articles where satisfactory fits are essential. In many instances the judgment of the members of the receiving department, acquired by long experience in stores department work, must be depended upon in accepting or rejecting material.

The results of the inspection and tests made by the receiving department should be transmitted to the purchasing department on a suitable form and all rejected material should be held until final disposition has been arranged for by the purchasing department. The results of the tests should be studied by the purchasing

* Report of committee of Purchasing and Stores Section—C. D. Weiss, chairman. R. V. Dodge, Jr., M. E. Waite.

department with the view of guiding future purchases, as an unreasonable percentage of unsatisfactory material always means expense, and in some cases costly delays and annoyances.

Inspections by Yard Gangs

Considerable inspection work must often be entrusted to yard gangs. Shipments of poles, cross-arms and lumber are generally handled in this manner and it is highly desirable to have a foreman available who is an experienced lumberman. In checking poles and cross-arms, the National Electric Light Association specifications should be followed and tests of preservatives for penetration can be left to these men, if the proper boring tools are made available.

Test Bureaus

However, a great many of the tests, to be of value, require special training which the average receiving clerk or yard foreman cannot be expected to possess. In the larger companies, it is, of course, logical to have a complete testing bureau, under the direction of an "engineer of tests." In such a department specially trained engineers, chemists and inspectors may be assigned to the test work for which they are particularly suited. But in companies serving smaller communities, say those with populations of 500,000 or under, such departments are hardly warranted.

Shop Tests

But, by all means, it is just as essential to make absolutely certain that only suitable materials are furnished for construction purposes. It is then most feasible to rely upon the foremen of the departments actually installing or using the articles to make the tests. In such instances, practical experience generally makes up, to a large extent, for the lack of technical education and training. Examples of such instances may include the testing of transformers, meters, motors, insulators, insulating oils and switches.

Accounting Features

A satisfactory way to handle the accounting of testing is the method used by the San Diego Consolidated Gas & Electric Company, which will be explained briefly. When shipments are received on which these tests should be made the receiving clerk applies for the formal authority for the performing of the work in the proper shop. This is the same kind of order as is issued for general construction or repair work in the company shops. The material, together with the "shop order" is then delivered to the shop. Special apparatus for the making of the tests regularly required has been installed in the various shops. When the tests are completed the results are entered on forms provided, the accepted material is placed in stock and the rejected material is returned to the receiving department to be held for disposition. As previously pointed out, the purchasing department is notified of the results and arranges for the disposition of the rejected material. The labor and material costs incurred in the testing are accumulated in the same manner as are those for any ordinary shop work and the usual percentage to cover the shop overhead expense is added. The total amount can then be distributed, adding the pro rata expense to the cost of the articles tested.

Simple Laboratory Tests

Many physical tests not requiring elaborate equipment can be made satisfactorily by an inspector of the stores department. Included in this classification may be listed bending tests, hardness tests, certain tests on cement, tests of galvanized hardware and permanency tests of paints. As the utility grows, additional testing apparatus can be added, including tensile testing machines, ovens and microscopes, until a real testing bureau is eventually established.

Relationship Between Receiving Department and Purchasing Department

As has been brought out, the receiving department and other departments making tests rely upon the purchasing department for sufficient data with which to control the tests and likewise the purchasing department depends on the reports of tests for guidance in dealing with the manufacturers. There are opportunities for much advantageous study in extending these co-operative relations.

Relationship With Technical Section

Also, as one manufacturer of an excellent brand of leather belting continually points out, there is always a big "IF" in specifications and here is where the Purchasing and Stores Section may work hand in hand with the Engineering Section in the testing of materials to common advantage. While the various societies for the testing of materials and the United States Bureau of Standards have prepared standard specifications for nearly everything imaginable, changes are always occurring in manufacturing methods, advancement in the arts which must be considered in keeping the specifications up to date and minute in detail. Then the purposes for which the materials are used in the electrical ultilities may vary from the general practice requiring certain alterations. Furthermore, it is essential to close loop-holes which are bound to occur in the so-called standard specifications and to correct the interpretations which have resulted in partialities. Many clauses may unintentionally prescribe the products of one manufacturer which, in reality, may be superior to those which will pass the formulas for testing. Again, in step with progress, additional items must be covered with adequate specifications. In all these things, the practical knowledge of the purchasing agents, the receiving clerks, the department superintendents and foremen can materially assist the technical section in the preparation of new specifications or in the alteration of existing ones.

Future Committee Work

Unquestionably there is a broad field for activity of the committee on inspection and testing of materials of the Purchasing and Stores Section, in conjunction with the Engineering Section, in order to secure for the electrical utilities supplies of the best article on the market for each purpose, at the same time permitting them to enjoy all the advantages of competitive bidding by reputable manufacturers.

Transportation Section[1]

Lubrication and Gasoline*

The internal combustion motor is one of the most difficult of all mechanisms to lubricate. Intense heat and high speeds combine to break down the protecting film of oil.

Lubrication is an agent that reduces friction. Correct lubrication may be said to exist when all bearing surfaces are kept separated by a lubricant which substitutes internal friction of the lubricant for destructive metallic friction between bearing surfaces. Good lubrication means more than keeping the motor filled with oil and changing the crank-case supply at more or less regular intervals, the extent of wear on the motor depending entirely upon the lubricating value of the oil used.

Motor oils are refined from crude petroleum. Chemically they are hydro-carbons; the chemical components of a molecule of any mineral oil are atoms of hydrogen and carbon. The principal difference in crude oil is in the ratio of the number of atoms of hydrogen and carbon that go to make up a molecule of the oil.

An oil salesman makes a selling point of the statement, "The measure of the quality of an oil is its specifications." This statement is no doubt true enough, but nothing is said in it about lubrication.

[1] **P. H. Ducker,** Southern California Edison Company, chairman. **J. M. Wainscoat,** San Joaquin Light & Power Corporation, vice-chairman. **J. R. Miller, Jr.,** secretary. **Arizona Power Company:** C. L. Mentzer. **California Oregon Power Company:** D. A. Runtard. **Coast Counties Gas & Electric Company:** A. E. Strong. **Coast Valleys Gas & Electric Company:** G. A. Peers. **Elko-Lamoille Power Company:** B. G. Bride. **Great Western Power Company:** J. S. Moulton. **Los Angeles Gas & Electric Corporation:** W. J. Schaeffer. **Pacific Coast Electrical Association:** S. H. Taylor. **Pacific Gas and Electric Company:** S. B. Shaw, E. C. Wood. **Pacific Telephone and Telegraph Company:** V. W. Dennis, W. H. Fairbanks. **San Diego Consolidated Gas & Electric Company:** L. A. Savage, C. D. Weiss. **San Joaquin Light & Power Corporation:** D. P. Mason. **The Southern Sierras Power Company:** C. H. Gray. **Truckee River Power Company:** E. D. Brown.

* Report of committee of Transportation Section—C. H. Gray, chairman.

One oil refiner states, "Motor lubrication is intangible; it is something on which you cannot put your hands. The inside of a motor cannot be seen. To attempt to test by trial in service, may be, in some cases, convincing, but is seldom entirely satisfactory. There is, however, an exact laboratory method of testing motor lubricating oils, accepted and recognized by all authorities on lubrication. These tests are as follows: viscosity, flash, fire points, gravity, purity, color and carbon."

Another refiner states, "The real test of any oil is the service it gives; how it stands up under fire. An oil specification is simply a tabulation of some of the physical characteristics of an oil; it is not a measure of the oil's lubricating value in any way. Specifications are of inestimable value to the men refining the oil for they furnish a check upon and a guide toward uniformity of product."

The question now arises as to how we, the users, are to know what is the best lubricant. It would seem from the foregoing that we must rely upon the integrity and the ability of the refiner. If the refiner is a large and successful concern we have every reason to believe that it has put lubrication into its product. No attempt has been made in this paper to discuss the merits or demerits of Eastern versus Western oil. Both have their adherents. Such a discussion would lead to endless argument.

An hour after a motor is started the dilution of new oil by fuel will cut the flash point greatly, and it has been said that the oil in the crank-case of the average motor car will show a flash point of one-half or even only one-third that given by the fresh oil.

Lubricating oil has two important functions:

Protecting the working parts. It must maintain a film between the metal surfaces, thereby preventing metal contact and wear;

Sealing the pistons and conserving the power. An oil that does these things will give the motor the necessary protection.

Transmissions and Differentials

Every automobile vehicle has a transmission and a differential. It is just as important to see that these are lubricated properly as it is to be sure your crank-case has plenty of oil.

A gear grease should:

Cushion and follow the gears, circulate and go to all bearings, not contain any insoluble matter, not contain acid, be of such body as to prevent loss of power by friction, prevent heat and not channel.

The transmission and differential should be cleaned out and refilled periodically, thus giving protection and insuring long and satisfactory service.

Vehicle and Body Design*

The purpose of this paper is to render reports on two recent developments in body design. The first of these is a consideration of a medium weight, medium cost, all-steel body for line construction trucks; the second, a new style body for use on small trucks in trouble or street-light maintenance service. Both of these designs are being tried out by the San Diego Consolidated Gas & Electric Company. Incident to the first consideration, several features of the truck design will be pointed out.

All-Steel Body

Figure 1 shows a 2½-ton truck recently purchased for electric line construction service, fitted with a vestibuled type or closed cab of combination steel and wood construction, a power winch with two nigger-heads, an auxiliary transmission giving speeds from 1.8 to 39.6 miles per hour at engine speed of 1,600 r.p.m., and an all-teel body having overall dimensions 96 x 144 in. Note the body and winch arrangement. Note the large "drop-type" window which has been provided in the back of the cab, giving the driver an unobstructed view of the winch and its cable.

Construction Details

A view of the under side of the all-steel body, showing the longitudinal and transverse members appears in Fig. 2. A filler strip of hard wood is placed between the body and the chassis to avoid cutting the steel members for rivet heads. The risers or sills are special channels of 10-gage steel, 5 in. deep with 2-in. flanges. The cross-members or joints, also special channels of 10-gage steel with 1½-in. flanges and 5¼ in. deep, are layed on the sills and electrically welded to

Fig. 1. A San Diego line construction truck with drop-window in the cab.

them. The side and end sills are made of ¼ x 4 x 3-in. structural angles. The ends of the joists are "joggled" to go under the 3-in. leg of the angle, in order to produce a level support for the ⅛-in. checkered floor plate, forming the deck. The channels are welded to the angles and the floor plates are welded in spots to both. Two pieces of floor plate are required to secure the 8-ft. width and the longitudinal joint is made by continuous electric welding. Provisions for stakes are afforded by cutting holes through the plate and the leg of the angle and welding in a stake pocket. A short joist only can be used over the rear axle, as it is necessary to give clearance for the dual pneumatic tires. It should be noted that no rivets are used in the assembly, all connections being made by arc welding. Three hold-down bolts of usual design are provided to secure each sill to the chassis and short filler blocks of hardwood are placed in the sill channels to resist crushing.

Weight—The bodies weigh approximately 1,250 lb., which is somewhat lighter than the weight of the sturdy, all-hardwood bodies previously built in the company's shop for line construction trucks.

Performance—Reports from users of this type of steel body in other lines of service have been most favorable and indicate that it is suited for public

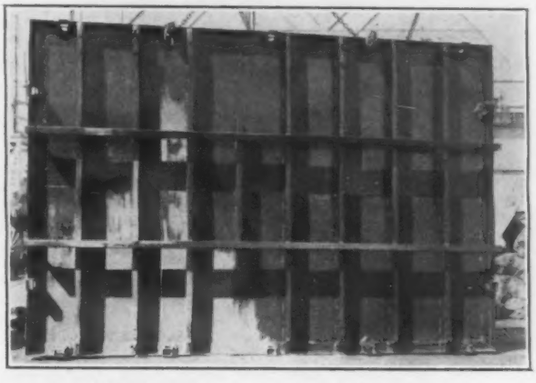


Fig. 2. Under side of all-steel truck body.

utility needs. The results in line truck work will be watched with interest. It is claimed that this type of construction is especially suited to the hot desert climatic conditions, in that the troubles from expansion and contraction to which the wooden bodies are susceptible are eliminated.

Trouble Car Box

An "open" and a "closed" view of a ½-ton truck equipped with a special box in an express type body for

* Report of committee of Transportation Section—C. D. Weiss, chairman.

"trouble" work is shown in Fig. 3. Both the box and the body are mainly of hardwood construction. The rack carrying the ladder is made of structural angles.

Description of Box—The interior arrangement was carefully planned for the convenience of the troubleman. Next to the cab are two locker spaces, one on either side, extending to the bottom or bed of the body, providing space for hand lines, boots, lanterns, bolt cutters, fuse pullers and other tools. In the next compartment are two sheet-steel trays and one wooden drawer, all of which extend the full width of the box and can be pulled out from either side, giving easy access to the material. Street lamps in cartons are conveniently stored on the trays and the partitioned drawer affords carrying space for rubber gloves and other articles.

The three drawers on the left-hand side at the back are designed and partitioned to accommodate the high

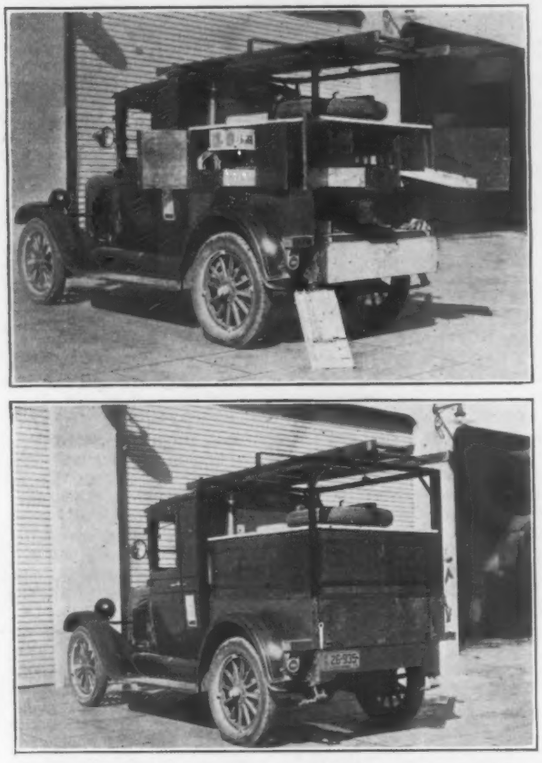


Fig. 3. Open and closed views of light service car used by the San Diego Consolidated Gas & Electric Company.

voltage fuses in glass tubes, sufficient sections being arranged to segregate the fuses by current carrying capacities. In the lower left-hand opening, three sheet-steel trays have been fitted, one of which has been taken out and is seen leaning against the rear spring shackle. These trays are divided to hold fuse links, there being separate compartments for each size. Hinged flaps have been fitted to keep the links in place. The two wooden drawers above hold fuse plugs and cartridge fuses.

Working Space—Between the stands of drawers a compartment or working space is provided. There is no bottom in this compartment so that articles in the express body can be reached without dropping the tail gate. On one side and at the front of this compartment are shelves in which holes are cut to hold time and transformer fuse plugs. This compartment gives the troubleman a dry place in which to apply fuse links to the plugs and a dome light has been installed to furnish illumination at night, thus dispensing with the use of unsatisfactory flashlights.

These two improvements constitute the only changes of importance which have been made in body design in the electrical division of the San Diego Consolidated Gas & Electric Company, and were the only features discussed by the Transportation Section.

Special Problems*

Since the committee's 1927 report the committee has grown to be of considerable value to members of the Transportation Section and has fully justified its creation. All members have not availed themselves of the material gathered together but those who have have indicated their appreciation by co-operating more closely with the committee and the work is increasing rapidly.

When questionnaires are sent out it is necessary to secure answers from all concerned so that a general average may be arrived at which is indicative of the best practice in effect. Such co-operation can manifest itself in a number of ways. A practical "shop hint," the results of a test on tires, brake lining, automobile accessories, etc., a report on the performance of a new model car or truck, specifications and prints on a new type of truck body—all of these are matters that would be of great worth to other members and would perhaps prevent a duplication of effort, for upon the receipt of such information it is condensed and the data passed on to all members in the form of a special bulletin letter.

As explained in a previous report, this committee does not feel qualified to offer personally solutions to all queries involving some knotty problem, but in its function as a central clearing house it propounds the question to other members in a questionnaire letter and from the replies received is enabled to provide the original questioner with a correct reply. In transportation work there constantly arise certain problems that must be met and contended with and it is here that the special problems committee can be of assistance.

Some months ago one of our members provided this committee with a print and full description of an apparatus for pumping out manholes. This device was very ingenious and was constructed from a discarded automobile motor and frame upon which was mounted a centrifugal pump making a portable unit of great flexibility. This information was passed on to members of the Transportation Section, some of whom adopted the idea and constructed pump units of their own. This is but one tangible example of how all can profit by the experience of an individual member and is quite in keeping with the motive that inspired the creation of the Transportation Section, which is to promote the interchange of ideas that will be of joint benefit to all concerned.

Another member furnished the committee some highly desirable information and cost figures in connection with replacing a gas lighting system with an electrical system on a truck. This data was promptly sent to all members in a bulletin letter and, I feel, was appreciated by them as undoubtedly they may have to contend with this problem in the future.

Some very enlightening replies were received in answer to a questionnaire mailed to members, seeking information on a practical type of pole dolly tail-light. Apparently a number of the member companies do not operate their trailer equipment after dark and hence have made no provision for lights, but other members have devised and perfected various types of tail-lights that are proving entirely practicable. A full and detailed description of these tail-lights was incorporated in a bulletin letter form and passed on for the information of members of this section.

A short time ago one of the member companies completed the construction of a new type pole derrick and winch attachment mounted on a line construction truck. This device was quite a radical departure from the conventional method of setting poles but after a thorough test it proved to be remarkably efficient. Photographs were taken showing the derrick in action and these views were printed and copies sent to all members. It is believed that much good will accrue from this as other members will undoubtedly copy the device and profit by the experience of the designers.

At the present time this committee is making an intensive study of methods of determining whether or not a truck has adequate brakes and what constitutes adequate brakes. Questionnaires have been sent members interrogating them on this subject and a brief report of the results of findings will be sent to all section members when all questionnaires have been returned and definite conclusions reached.

* Report of committee of Transportation Section—J. M. Wainscoat, chairman.

Shop Practice*

To generalize on this subject of shop practice as applied to all industries, the first fundamental is the organization. It must be built of business principles, legal organization, financial planning and efficient engineering principles. The next item of importance is the subdivision into departmental organizations. In this way, the auditing and accounting may be of value in the proper control of overhead and as each department carries its own overhead and a part of the general administrative overhead, the problem can be properly administered to effect economical operation.

Shop Practice

The supervision of the functioning of the organization is a problem that calls for personal discipline and must be established along recognized lines of authority and must function according to them. Proper supervision eliminates the handling of small details personally and should be turned over to the departmental heads; supervisors should originate ideas and provide means of having them carried out. In choosing subordinates, every means should be used to select men who are worthy of confidence. A man should not be given a half-hearted responsibility so that he can hardly feel a sense of personal credit for success and yet is certain to be blamed for failures.

The foreman has come to realize that he is responsible for the wise and economical use of materials, and that it is good foremanship to lead his men, rather than to drive them. The foreman naturally has no control over, or relationship to, the selling and administrative expense, but is intimately connected with the factory costs, which constitute one of the big factors in the total cost that it takes to produce the product. This cost accounting system is the work of the costs department, and upon the accuracy, completeness and adequacy of these original records depends the accuracy of keeping costs.

The greatest responsibility of the superintendent, or foreman, lies in assuring that the records that he turns over to the cost accounting department are true statements of what has been done and that it has been charged out correctly. It is the custom of some progressive companies to furnish the superintendent with regular statements showing the efficiency and costs of his department. The average superintendent or foreman can be shown the value of watching certain elements; by so doing, he can make his work easier and get more efficient results, but the chief difficulty is that cost information collected at great expense, often comes to him so late that it cannot be used as a means of control, but is only of historical value. The right kind of a cost system, however, will show specific information on operations of his department and it should be prompt and not a month or so late. Many managers of industries in their development of efficient and economical methods have applied the time study and motion study to their plants with great success. With time study, two distinct elements are the human and the technical analyses.

Shop Analysis

The first operation of a time study observer is the collecting of all the information available pertaining to the job. In many cases the operator has learned a few trade secrets and will not part with them, so the observer will have to content himself with the following order of work: Determine if the operation to be studied is necessary; get data on life of tools and miscellaneous stoppages; make detailed investigations; make the time study; write up the analysis and instructions and instruct the workman. During this time he should observe and analyze the general conditions governing the operation and may be assisted by the following suggestions: Is the machine the best for the job? Is the machine properly located? Can the machine, jig, or fixture be improved? Can any of the details be eliminated? Is the operation safe for the workman? Are the limits of the work closer than necessary and the requirements of the tools as to speed, feed, material, handling, etc., what they should be? Haphazard buying of shop machines and tools is a costly method. Investigations, comparisons, and the experience of others should guide their purchase. The location of a machine is important for there should be sufficient light for the workman to enable him to set tools properly or place parts in the die or fixture without fumbling. The relative position of the operator with regard to preceding and succeeding operations is another important factor.

After determining the best method of doing the job, the time study man must train the operators to do the operation in that way, though he has to break the workman of his old habits and teach him new ones. This must be handled with tact and diplomacy so as to not cause friction.

Safety

Another phase of the problem of shop practice is the safety committee. Plant safety problems involve three essential features: education, engineering and safeguarding. However, these elements will fall short of their objectives unless they are sponsored by an active, enthusiastic safety committee. Some of the essential functions of the safety committee are the following: (a) To be a channel through which a frank discussion of safety policies and practices may be had. (b) To make periodical inspections of the shop and submit definite recommendations. (c) To review the elements which contribute to an accident and make recommendations to eliminate a recurrence. (d) Constant education and instruction. (e) To receive suggestions for the further advancement of safety appliances. (f) To improve the spirit of co-operation and willingness between employees and management. (g) To make the safety plans, as developed in their committee meetings a part of the operating policies on their own particular job. It is an established fact if the "key men" are well instructed and well organized in safety problems the results of this education will eliminate many hazardous operations with a saving of expense.

As we are interested in the particular functions of the transportation departments of the electric light and power companies, it might be of some interest to outline briefly the methods used in the repair and reconstruction of vehicles used in this field of operation.

Organization and Procedure

The organization is divided into the following departments: administrative, sttaistical and operating. Each day the superintendent receives a short report from each foreman giving a brief account of the work and the foremen in turn receive their orders for the day. All verbal statements made at the meetings are put in writing as soon as possible, in order to avoid doubt and confusion later; instructions are made definite. Time and costs on previous jobs are always available from the statistical department for comparison purposes. The purchase and storage of parts and materials receive careful attention and money is saved by regulating the purchases to conform to the estimated work to be performed.

Bulletins are issued by the department superintendent's secretary to forman and workers. These bulletins include discipline, rules of a technical nature and general service rules; all are more or less ironclad and of a military nature that must be obeyed without comment.

The workers are divided into classes; men who prove themselves more proficient than the average are given a higher grade of work and better pay. The men naturally strive to get into the higher classes thus developing initiative and at times executive ability.

Consider now the procedure a vehicle goes through that is brought into the shop for overhauling or reconditioning. It is first taken over by the repair operating department. The dispatcher of the transportation department is ordered to replace the unit and then the unit is received at the inspection bay where the extent and classification of reconditioning cost and materials are noted on a special form which is attached to the vehicle and later becomes a part of the mechanical history which is filed in the statistical department. This information is then placed in a mechanical audit form that estimates the segregated cost of each operation and is given to the superintendent where replacement, salvage, fixed charges and other data are considered before the repair operations are started.

The first step in the shop system is that of dismantling of equipment and a thorough cleaning of parts. On completion of this operation an inspection is made and the requisitions for materials are procured. The foreman then assigns various parts to their respective stations, such as motor to the motor room, transmis-

* Report of committee of Transportation Section—E. C. Wood, chairman.

sion and the various parts to the respective departments that are equipped to specialize on this detail. The detailing of these operations is an interesting application of time study as by combining the variety of types and makes handled it has developed that efficient operating can be established by combining many jigs and fixtures to cover a greater scope of this work.

Upon completion of the assembly of the various parts of this equipment the parts are taken to the assembly bays where the unit is reconstructed and given average mechanical adjustments and subsequently sent over the proving course. This area has been selected to give the maximum conditions that a unit will have to develop for this section of operation. The unit then is returned to the paint department for the final finishing before being sent into the operating field. The practice of the shop is such that running repairs, fueling, garaging and adjustments are given the attention of an efficient crew that has a definite program and that has facilities enabling it to operate efficiently and economically.

Shop Layout

Some thought should be given to the shop layout, particularly where it is necessary to perform work on the floor. However, in quite a few public utility shops the amount of work done on the floor has been reduced greatly in many instances where a close watch is kept on shop efficiency. It is a well known fact that mechanics cannot work to advantage while lying, sitting or in stooping positions on the floor. There has been some thought as regards the height of the average work bench that has been found best for all-around work. There is a marked gain in efficiency where the unit is taken to the work bench, or the work bench taken to the unit, instead of doing the work on the floor. The "old school" idea of the "handiness of the floor" probably is responsible for the fact that the floor is used for so many different purposes. When a mechanic starts on a job he places a few tools on the floor and goes for more. While a filthy floor is universally condemned, it is responsible for an improvement in shop conditions in many instances, paradoxical, as this statement may appear. Experience with mechanics shows that they dislike working on a dirty floor and that to do so reduces their work to a minimum. Rear axles in many instances are left on the floor because of their weight and size. Portable work benches and even rear axles can be supported on stands on variable jacks made for this purpose. Reference to tool catalogs will provide more data on this subject.

Cleanliness is next to godliness and general housekeeping is the first step towards increasing shop efficiency. All discarded parts, particularly salvaged parts, should be placed in a stockroom provided for that purpose. A few bins and cabinets suitable in size will make it easier for mechanics to place their parts where they can be found when component parts are to be made up. This not only eliminates loss in parts, but reduces loss of time, tends to keep the floor clean and also reduces tripping and falling hazards.

"Front-ends" commonly are rebushed and replaced while remaining in the chassis. This operation entails considerable stooping on the part of the mechanic and is a man-hour eater. A survey of public utility work shows that a small "creeper" with low backrest may be used for part of the work. Also that light-car type front assemblies can be made up from the bench. This enables the man to be in an upright position and do his work where plenty of light is available. It is found in larger fleets where the unit replacement plan is in vogue, that front-end systems are exchanged as units, and here again these repairs are made on the work benches.

Another simple plan for keeping tools and small parts off the floor is that of placing the mechanic's' tool kit on a tray mounted on casters. Such a tray is moved about in company with the mechanic and if he acquires the habit of replacing tools on the tray no tools need be scattered about the floor. Another way of overcoming the disadvantage of working on the floor is to provide open-end pits or ramps in which the man can work underneath the chassis, while standing. The closed-in pit not only is a fire hazard, but also is a safety hazard and has a tendency to accumulate dirt and contamination. It is difficult to enter and leave, and is a man-hour eater. This statement is made advisedly and as a matter of record.

Improved Facilities

Special tools are an important aid in efficient service to the public utility fleet operator, and an important factor in comparing his shop costs against the flat-rate shop costs of the respective dealers and shop organizations. Some automobile manufacturers are urging their respective service managers to improve facilities to give better service and at a lower cost. Likewise fleet operators in public utility work should be "up and at it" to make the organizations as efficient and as economical as possible. It should be possible to have utility shops so organized with special tools and shop personnel, that the utility shop can compete with, and in some instances show a tremendous saving over, the contract flat-rate of the outside shop. This comparison of "inside" vs. "outside" costs should be the yard-stick of shop analysis. However, the shop that has only one certain make of car has the advantage of using special tools and jigs and personnel trained on that one particular make of automobile, whereas fleet operation does not permit such specialization. Still the utility shop must face and solve the problem of making the system generally effective and efficient.

A study of the various service bulletins made out by the various manufacturers on their equipment gives the operator the advantage of purchasing various special tools that may be used to advantage on certain cars. There is another element in regard to shop practice, and that is the human equation involved. Experience shows that special tools will be shelved and the work which should be done by them will be done by slower and less efficient methods. This involves an educational program which will not be touched on at this time. Suffice it to say, however, that every special tool that is bought or made for shop use should be intelligently demonstrated by the foreman to the entire shop personnel in order that the savings possible through full use of the special tool may be realized, and not hampered by ignorance or prejudice on the mechanic's part.

A few words regarding the budget plan not only for operating the shop, but also as applied to vehicle operation are in order. A survey shows that a few shops operate on a budget system while many do not. Four or five years' experience with the budget system in the Pacific Gas and Electric Company shops has demonstrated it to be a wonderful "tool" with which to work. It is possible to do several things with a budget which would not be possible otherwise. The first and most important is to advise the management of the cost of previous years and probable cost of the current year based upon the previous year's findings. Also the budget system gives a definite idea or "bogey" within which to work. Further if anything is left from the budget it well may be called an "efficiency" profit. Lastly, if the budget of previous years is exceeded, it shows up promptly as a danger signal indicating that there is something wrong.

There is another important subject to which the Transportation Section, P.C.E.A., should give some "real honest-to-goodness thought" and that is, how many mechanics service a given fleet. The section should ask that question of its members and a paper could be prepared on this important subject. The number of men needed varies according to whether all or only part of the repair work is done in the company shops; whether or not specialized work such as repairing of electrical systems, carburetors, tires, painting, upholstery and cylinder re-grinding are done in outside establishments; and whether or not a shop is worked in dual capacity, working in conjunction with physical departments. These are some of the variables that will have to be taken into consideration in bringing up a comparison report. This is a very important subject and a subject which is being given considerable thought in the East. Just how efficient are we in this respect?

Unit Replacement System

The "unit-replacement" scheme where the actual repairing of the unit involves considerably more time than is taken by mere exchange of a rebuilt unit for the worn unit, is bound to lessen greatly the total time the vehicle must spend in the shop. It is obvious that if the repairing of a certain unit on a vehicle can be accomplished by the simple process of installing a completely rebuilt unit, the fleet operator has been materially benefited by the reduced "lay-up" time thereby secured for the vehicle. There is another angle to this unit-replacement idea: it eliminates the necessity for purchasing spare equipment and thus cuts down on equipment costs.

Northwest Association Year in Retrospect

By A. C. McMicken
President, Northwest Electric Light & Power Association.

LOOKING out over the wide range of activities of the Northwest Electric Light and Power Association from that central vantage point afforded by the president's office, one is impressed by the vast amount of individual energy that has been put into association affairs during the past year. Ours is an association widely extended from a territorial standpoint but lightly manned in comparison to other geographic divisions of the N.E.L.A., because our territory, being thinly populated, is served by only a few companies large enough to maintain extensive organizations. This peculiar physical characteristic imposes on us conditions under which comparatively few men and women are available to carry on the multitudinous activities of a competent geographic division of the N.E.L.A.

A. C. McMICKEN

It is interesting to note that these activities are carried on by 44 committees manned by only slightly more than 200 men and women from thirteen utility companies and six manufacturing and supply companies. When it is understood that some of these companies are able to furnish for committee work only a few from their limited personnels, it will be recognized that the bulk of the work falls on the organizations of the eight larger companies, and that since some duplication in manning committees is necessary, a considerable burden is shouldered by a few individuals.

Attention is invited to this condition not with the idea of minimizing the efforts put out by the smaller companies, which are commensurable in every respect to those of the larger ones. Rather the intention is to throw emphasis on the association's accomplishments of the past year, as exemplified in part by the reports published herein, and to extend to those responsible for these accomplishments hearty thanks for their faithful co-operation and able execution of assignments. An examination of the reports that follow will indicate that committees have attacked many important problems in all phases of utility company operation. Some committees not reporting at this time will have interesting subjects to present at the Twenty-First Annual Convention in Portland, June 19-22, 1928, to which all are cordially invited.

Space is too limited to permit a detailed summary of association activities, but a brief statement concerning each of the four sections is possible and appropriate.

The Accounting Section, besides co-operating with national committees, has greatly broadened the scope of its activities to provide for the study of problems outside the strictly accounting field but of considerable importance to company executives. A comprehensive study of taxation has been undertaken during the past year, and studies on similar subjects will be taken up from time to time as the occasion warrants. This section is also serving other association committees by compiling data for their use.

The Commercial Section has been particularly active with nine committees functioning under its three bureaus. The eight reports published herein contain many suggestions valuable to every member company, and should receive the attention of the executives as well as the commercial department personnels.

The Engineering Section, long considered nationally as one of the best organized and ablest functioning engineering sections of all the geographic divisions, held its fifth annual general meeting in Spokane in March, and the proceedings of that meeting, to be published separately as has been the custom, will contain a wealth of material bearing on local and national problems of direct interest to Northwest companies.

The Public Relations Section has stressed in its activities the importance of the employee in developing good relations between the utility company and its public. With the idea of interesting the rank and file of company organizations in utility problems, the section committees have conducted public speaking and essay contests, the results of which will be presented at the convention.

While the four sections have been occupied during the past year with the study of specific problems in their particular fields, the program to be presented at the convention itself will be of general interest. Among the subjects that will be discussed by the speakers will be load-building, taxation and public relations.

Following last year's precedent to a considerable extent, the convention program will be divided into four general sessions held in the morning, leaving the afternoons free for the enjoyment of a variety of entertainment. Each session will be conducted by one of the sections with programs pertinent to the section's problems but of a general enough nature to appeal to all. In addition, several nationally-known speakers will discuss general topics of interest to the industry. The electrical industry of Portland will be host to the convention and has completed plans for the comfort and enjoyment of the expected visitors.

May I take this opportunity personally to invite the association membership and all others who might be interested to join us at Portland in June.

Accounting Section Reports

Customer's Records Committee[2]

This committee in preparing for the work for this year, tried to develop subjects and prepare papers which it thought would be of value to the utilities, by devoting effort to research work and submitting papers on certain practices that had previously proven their value by actual test in operation.

Although the committee was divided into three divisions each to develop a separate paper, joint meetings were held and ideas exchanged. The papers submitted herewith are the results of interest manifested by the individual members of the committee and I wish to take this opportunity of expressing gratitude to each member for the wonderful co-operation displayed.

The report of the Customers' Records Committee is subdivided as follows:

1. A Register Sheet Plan for Customers' Accounting.
   Written by: N. B. Whittier.
2. A Stub Plan for Customers' Accounting.
   Written by: B. H. Parkinson.
3. Uniform Application for Opening Service Account.
   Written by: M. J. Wilkinson.

The committee is submitting this report with the hope that those contemplating a change in their customers' records will find the information contained herein of value to them.

A Register Sheet for Customer's Accounting

By N. B. Whittier*

There are three general plans of customers' accounting which are in use today in connection with machine bookkeeping, namely the ledger plan, the register sheet plan and the stub plan. These plans, however, are not entirely distinct in their application. They are individual only to this extent—that the ledger plan provides a continuous record of the charges and credits for each customer; the register sheet plan sets up the debits and credits for a number of customers on one page which is rewritten each month; and the stub plan uses a copy of the bill as a ledger record, the stubs being removed from the active file as they are paid.

The ledger plan has several advantages, the principal one being that it provides a continuous record of each customer's account. However, it is generally considered slower than either of the other two plans and is not adaptable to centralized billing for district offices. For these reasons, it is not used to any great extent in the newer machine installations which are being made.

The register sheet plan and the stub plan are predicated on the theory that 80 per cent to 85 per cent of public utility accounts are settled currently and therefore the ledgers need show only the unpaid balances at any particular time. It is felt that the advantages of either of these two plans greatly exceed the additional time which may be required to analyze an occasional account for a period of time.

With slight modifications it is possible to adapt either plan to block rates or rates based upon demand. They are both in use for joint billing of various classes of utility services and they are both practical for joint billing of utility services and merchandise accounts. The two plans are extremely flexible and there are almost as many ways of accomplishing the various results in connection with customers' billing as there are innstallations in effect. It cannot be said that there is a distinct register plan or stub plan, but rather that

Form 616 PORTLAND ELECTRIC POWER CO.

METER LOCATION

DATE	SUSPENSE ORDER No.	TRANS. ORDER No.	TRANSFER TO OR FROM

DIALS	CONST.	FLAT RATE	MIN. KWH.	MIN. CHGE.	REV. CODE	FIRST	SECOND	THIRD
						26	14	100

READER	DATE	READING	KWH. CONSUMED	GROSS BILL	DISCOUNT	PREV. BAL.
3	5/11	19461				
4	7/10	20098	157	632	32	
7	9/9	20744	176	670	34	63 CR
9	11/10	21442	198	714	36	130 CR
6	1/9	21689	217	757	38	
3	3/10	22831	142	607	30	
2	5/11	23958	127	559	28	60 CR
2	7/11	24121	163	644	32	
3	9/9	24296	175	668	33	
2	11/9	24486	190	698	35	
3	1/10	24726	240	798	39	698

Fig. 2. Meter reader's sheet used by the Portland Electric Power Company.

[2] **M. J. Wilkinson,** Pacific Power & Light Company, chairman. **Pacific Power & Light Company:** B. H. Parkinson, vice-chairman. **Portland Electric Power Company:** N. B. Whittier. **Puget Sound Power & Light Company:** E. P. Donegan.

* Report of customer records committee of Accounting Section.

FORM 433 PORTLAND ELECTRIC POWER CO. 320 ALDER STREET PORTLAND, OREGON ATWATER 8161

METER READING DATES
PREVIOUS November 9, 1927
PRESENT January 10, 1928

AMOUNT PAID

Please enclose this stub with your remittance

NO DISCOUNT ALLOWED AFTER January 25, 1928

PLEASE REMIT GROSS AMOUNT IF PAYMENT IS MADE AFTER THE DELINQUENT DATE

PORTLAND ELECTRIC POWER CO. 320 ALDER STREET PORTLAND, OREGON

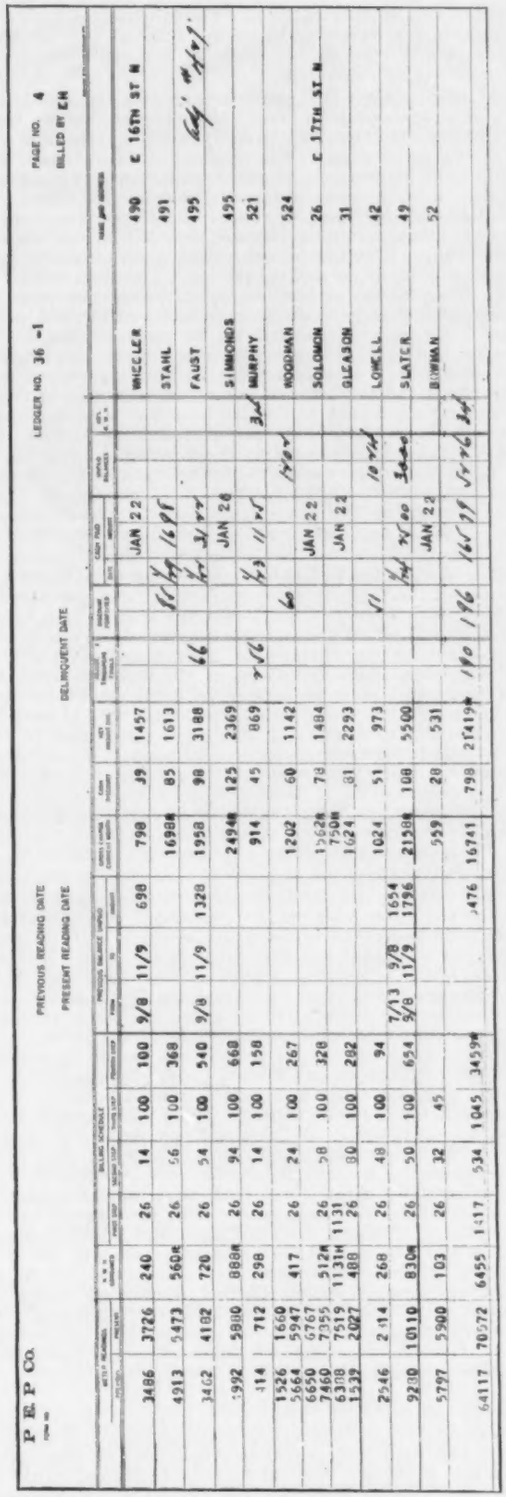
METER READINGS PREVIOUS	METER READINGS PRESENT	K.W.H. CONSUMED	BILLING SCHEDULE FIRST STEP	BILLING SCHEDULE SECOND STEP	BILLING SCHEDULE THIRD STEP	BILLING SCHEDULE FOURTH STEP	PREVIOUS BALANCE UNPAID FROM	PREVIOUS BALANCE UNPAID TO	PREVIOUS BALANCE UNPAID AMOUNT	CHECK CHARGE CURRENT MONTH	CASH DISCOUNT	NET AMOUNT DUE
3486	3726	240	26	14	100	100	9/8	11/9	6.98	7.98	.39	14.57

RESIDENTIAL SCHEDULE
FIRST STEP K.W.H. @ MIN. THIRD STEP K.W.H. @ 2C
SECOND STEP K.W.H. @ 7C FOURTH STEP K.W.H. @ 2C

COMMERCIAL SCHEDULE
CODE "A" K.W.H. @ MIN. CODE "I" K.W.H. @ 9C
CODE "B" K.W.H. @ 12C CODE "J" K.W.H. @ 8C
CODE "C" K.W.H. @ 10C CODE "K" K.W.H. @ 1½C
CODE "D" K.W.H. @ 9C CODE "L" K.W.H. @ 1½C
CODE "E" K.W.H. @ 7C CODE "M" K.W.H. @ 1C
CODE "F" K.W.H. @ 6C CODE "N" K.W.H. @ 0.8C
CODE "G" K.W.H. @ 5C CODE "P" K.W.H. @ 0.6C
CODE "H" K.W.H. @ 4C

CASHIER'S STAMP

Fig. 1. Bill and stub used by Portland Electric Power Company.



P. E. P. Co.

LEDGER NO. 36 -1 PAGE NO. 4

PREVIOUS READING DATE DELINQUENT DATE BILLED BY EH

PRESENT READING DATE

METER NUMBER	READING	K.W.H. USED	BILLED VOLTAGE: HIGH STEP	BILLED VOLTAGE: LOW STEP	BILLED VOLTAGE: TRANS. STEP	PREVIOUS BALANCE UNPAID: FROM	PREVIOUS BALANCE UNPAID: TO	PREVIOUS BALANCE UNPAID: AMOUNT	GROSS ENERGY CHARGE	GROSS ENERGY CHARGE: AMOUNT	NET AMOUNT DUE	DISCOUNT TAKEN	ORIGINAL PAYMENTS	CASH PAID: DATE	CASH PAID: AMOUNT	OPEN BALANCE	INIT.	MAP AND NUMBER	
																		WHEELER	490 E 16TH ST N
3486	3726	240	26	14	100	100	9/8	11/9	698	798	99	1457			JAN 22				
																		STAHL	491
4913	5473	560*	26	66	100	368				1698*	85	1613							
																		FAUST	495
3402	4102	720	26	54	100	540	9/8	11/9	1328	1958	98	3188			JAN 26				
																		SIMMONDS	495
5992	5800	888*	26	94	100	668				2494*	125	2369							
																		MURPHY	521
314	712	298	26	14	100	158				914	45	869							
																		WOODMAN	524
1526	1660																		
5664	5947	417	26	24	100	267				1202	60	1142							
6650	6767														JAN 22			SOLOMON	26 E 17TH ST N
7460	7355	588*	26	58	100	328				1362*	78	1484							
6308	7519	1131*	1131	80	100	282				750*									
1532	2027	488	26							1624	81	2293			JAN 22			GLEASON	31
																		LOWELL	42
2546	2814	268	26	48	100	94	7/13	9/8	1654	1024	51	973							
							9/8	11/9	1796	2158*	108	5500						SLATER	49
9230	10110	880*	26	50	100	654									JAN 22				
										559	28	531						BOWMAN	52
5797	5900	103	26	32	45														
64117	70572	6455	1417	534	1045	34594				476	16741	798	21419*						

Fig. 3. Register sheet used by the Portland Electric Power Company. This sheet is a carbon impression of each succeeding month's customer bills.

each installation is an adaptation of a particular plan to meet the local requirements.

The Portland Electric Power Company has developed a register sheet plan which is operating successfully on 25,000 accounts based on a demand rate structure. Approximately 20,000 accounts are located in the city of Portland, about 3,000 are in Oregon City, 15 miles distant, and 2,000 are at St. Helens, about 30 miles distant. Residence accounts in Portland and Oregon City are billed on a bi-monthly basis; business accounts and all St. Helens accounts are billed monthly. We have not yet attempted to bill merchandise in conjunction with the service accounts, principally because of the bi-monthly billing.

Meter Readers Sheet

In the Portland district, ledger accounts are arranged geographically, and the meter reader follows each street through to a definite boundary. This facilitates meter reading, posting of cash and locating accounts. In rural territory where the streets are not numbered, the ledgers are arranged alphabetically, making it necessary for the reader to rearrange his sheets before leaving the office and again before turning them back.

The meter reader records the meter index and computes the consumption. This is required in order to force him to check his reading and to investigate the reason for any abnormal consumption. We have had instances of "pool hall" readings, but we find that a reader cannot practice this method very long without it coming to our attention.

After the reader's book is turned in, it is held for 36 hours to permit any card readings to be mailed in. If they are not received within this time, the reading is estimated and the bill marked accordingly.

The receipt of the meter book is a signal for the addressograph department to prepare the bills and the register sheet, and for the balance clerks to close the corresponding ledger. In order to satisfy the requirements of certain people in the organization who feel that a continuous record of each customer's bills is absolutely essential, we enter the gross amount of the bill and the discount on the meter reader's sheet, as will be seen on the sample form. This is not essential to the successful operation of the register plan from an accounting viewpoint and is not ordinarily embodied in the plan.

The meter reader's book is then routed to the balance clerks, who post the unpaid balances from the previous register sheet to the right-hand column of the meter reader's sheet. If merchandise were to be billed jointly with utility services, it might be handled in a similar manner. The reader's book then contains complete information for the billing machine operators.

Register Sheet

The register sheet is a carbon impression of the customer's bills with the customer's name and address on the right-hand margin. We have conducted experiments with the Elliott-Fisher, the Underwood, the Remington and the Burroughs bookkeeping machines in connection with this work with varying degrees of success.

The machines verify the meter reader's calculation of the consumption. They show the kw.-hr. remaining after each step, if the billing is to be broken down by steps, and prove that the total of all the steps agrees with the total consumption. They add the previous balance to the gross charge for the current month and subtract the discount to determine the net amount due. In addition to this, they carry the cumulative totals which appear at the bottom of the page. Subtotals are taken for each page and a grand total at the end of each book.

The register sheets are turned over to a proof clerk who verifies the gross charge by multiplying the kw-hr. at each step by the rate for that step. She also checks the total of the unpaid balances with the previous register sheet and then releases the bills for dating and distribution.

The classification of earnings and kw-hr. used is obtained with a minimum amount of work. Commercial accounts are kept in one section of the ledger with the residence accounts in another, and a subtotal is obtained for each section. This leaves only three classes of service to obtain from our residence books, namely ranges, heaters and lighting. Ranges and heaters are coded on the bill and register sheet with an "R" and a "H" respectively. These are then recapped and subtracted from the total earnings to obtain the lighting revenue. The procedure is similar with respect to the commercial revenues.

Cash is posted to the register sheets by hand, although it can be done successfully by machine. Cash stubs are sorted in advance and a control set up for each section of twenty books. The register sheets show the net amount due. If the customer pays this

amount, the credit posting is made with a dating stamp; if he pays other than the net amount, the posting is made in ink. At the expiration of the discount period, the forfeited discounts are entered in the column provided for this purpose. Final bills and adjustments are entered in the columns provided for additional earnings and kilowatt hours used.

At the end of the billing cycle, the unpaid balances are extended in the right-hand column and each page is balanced. The unpaid balances are then posted to the meter reader's sheet from which medium they are picked up on the bill and the new register sheet.

If desirable, extra copies of the register sheet can be prepared for a proof sheet for a recap of the earnings or for the use of the home office and a local office. We soon found, however, that one sheet was sufficient for all purposes.

Advantages of Register Plan

The advantages which can be claimed for the register system are as follows:

1. It is compact—making it possible to carry as many as 20,000 current accounts in one binder or to have 10,000 accounts for two billing periods in one binder.
2. It makes it possible to prove and balance 50 accounts at a time rather than a complete meter book, thereby reducing the work involved in locating balances.
3. It eliminates the extra proof sheet which is necessary with the stub plan so that there is only one record to change for corrections.
4. It is probably the fastest system in use for posting cash. Fifty accounts in numerical sequence are visible at a glance, making it unnecessary to thumb over as many ledger sheets or stubs to locate one item.
5. It eliminates the possibility of lost and misfiled stubs, which is ever present with the stub plan.
6. Expired ledgers are more easily filed and are much more suitable for reference than the stubs under the stub plan, because if stubs are taken from the file for analysis, they must be put back again.
7. It is easier to take off a trial balance from a sheet than it is from either cards or stubs.
8. It is extremely satisfactory for analyzing delinquent accounts, which stand out in a column by themselves.

A Stub Plan of Customers' Bookkeeping and Billing

By B. H. Parkinson*

The subject of this paper is a stub plan of customers' bookkeeping and billing in use by the Pacific Power & Light Company. Stub Plan, I am sure, does not describe it, yet I am not inclined to coin a new name. I rather prefer to attempt a definition of a stub plan—a definition which will permit the title, "Stub Plan," to imply characteristics rather than detail.

History of Customers' Accounting

Before presenting a definition I would like to review some of the evolutions in accounting records. I want to start with the list of debtors when each transaction with a debtor was written on a sheet in chronological sequence. Then it probably occurred to someone that it would be much easier to gather the amounts owning by a customer in one place, in other words, a detailed accounts receivable ledger in bound book form, several spaces for accounts on a page. It then seemed advisable to number the pages and have an index so that the accounts could be more readily located. Then came the confusion of re-indexing whenever an account filled the allotted space and the result was a loose leaf ledger.

This loose leaf ledger was a violation of an old principle and a howl was raised by the conservatives that the new theory, while being convenient, was entirely unsound. It permitted the recopying of accounts which was conducive to fraud, it was possible to misplace or lose a sheet and would cause endless confusion in balancing. Nevertheless, it was proven that the plan was fraud-proof enough, that the balances could be controlled and that increased volume of business demanded a simpler and less expensive plan and the new theory stuck. We then had the individual loose leaf sheets with the name at the top, a separate sheet for each customer forming a continuous record of his account, and another form of loose leaf sheet with names down the side of a master sheet with unheaded insert sheets—one insert sheet for each month to permit the account to be posted horizontally—or in other words, the Boston ledger. The Boston ledger, for purposes of economy in balancing a "hand kept" ledger, broke away from the principle of a continuous record of a customer's account.

At this time we had another form of simplified bookkeeping, known as the bill and charge system, best exemplified in the corner grocery store, a sales book for each charge customer. The original slip constituted the bill to the customer and the carbon copy formed the charge or customer's account. Then it was discovered that an adding machine could print and that small adding machines could be used in conjunction with a typewriter. These were immediately employed in the work of posting as well as adding. This furthered the idea of doing more than one operation at one time by using carbon paper—another violation of an old principle. Heretofore, the ink to be used by the bookkeeper had been selected with discriminating care for by all means it should be made difficult to erase and should not fade with time. An adding machine or typewriter ribbon was a fair substitute, but a carbon copy was wholly unacceptable. Nevertheless the carbon idea stuck. It became necessary to adapt accounting forms to machines which caused a radical change in the size and appearance of the forms. This change of form soon caused the "bill and charge" idea to be known as the "ledger and statement," and later the Boston ledger to be known as the "register plan."

The American Telephone and Telegraph Company developed the idea, because its monthly charges to customers were fixed or "flat," that the billing data could be embossed on an addressograph plate from which the bills could be prepared month after month without rewriting, also that a repetition of the impression of the addressograph plate on a small ledger page or stub attached to the bill would be an economical way of posting the consumers' ledger. It was more convenient to file these ledger pages or stubs in a file than in a loose leaf binder. As practically all of the accounts were paid in full each month, it developed to be much simpler to stamp these stubs "paid" rather than enter the amounts paid. For convenience in balancing, a paid file was established to which all paid stubs were transferred.

The Public Service Company of New Jersey was confronted with a different problem in working out the stub plan. The charges to customers were not the same each month, therefore a bookkeeping machine was employed to repeat automatically on the stub the date on the bill. A detailed report of this plan was published under the title of "Bookkeeping Without Books," which title was grossly misunderstood. Those who did not understand the plan ridiculed the idea of recording the accounts receivable of a business having in excess of fifteen million dollars annual gross revenue on mere scraps of paper. It was rumored that, because it was so difficult to locate an error or strike a balance, it was necessary to write off any differences. The word "books" I am sure was meant to be taken literally, that is, bookkeeping without ledger binders or bound books. It was actually a loose-leaf plan with the loose ledger leaves or stubs filed in a tray rather than in a binder, using the principle of the old "bill and charge" plan, or the "ledger and statement" plan of producing the bill and the ledger, except that they were produced by a repeating process, rather than a duplication process, and had added the cash posting feature of stamping the ledger records "paid" instead of making an actual entry. Railroad companies and express companies have for years been using a stub plan through a carbon.

Definition of Stub Plan

The point that I have tried to demonstrate thus far, is that the stub plan is not new in theory or principle. It is the same old plan of "bill and charge" with a loose leaf ledger. It can be operated in as fraud-proof a manner or as "slip shod" as any other plan. It can be a hand method or a machine method, and any one of several machines can be used. The duplication of bill and ledger record can be made either through a carbon paper, by a repeat print process, by the use of copying ink or copying ribbon and then duplicating on a gelatine roll duplicating machine, or by actually writing the ledger and bill separately and balancing them against each other. The ledger records can be filed in post binders, prong binders or in trays. They can be filed by billing period or by customer's account to form a continuous record of billing at each address. Cash payments can be recorded either by making actual en-

* Report of customer records committee.

tries on the ledger records or by stamping the ledger record "paid."

Therefore I should say that the only definition that can be given for a stub plan of billing is as follows:

A loose leaf system of customers billing and bookkeeping wherein the bill and ledger sheet or ledger record are produced at the same time, with a separate ledger record provided for each customer for each billing period.

The ledger record may be an exact duplication of the customer's bill or a duplication only of what may be considered the essential data. Beyond this the detail of a stub plan will vary depending upon what the directing accountant may consider constitutes a good accounting record. The economies which a company may wish to accomplish in customer bookkeeping and billing, the number of classes of service rendered by the company, the number of tariffs of service, whether the company is selling merchandise or not, and the number of customers per district office are some of the factors entering into determination of the kind of detail to record.

Factors Leading to Adoption of Stub Plan in Pacific Company

The Pacific Power & Light Company and the companies operated by it are engaged in serving electricity, gas and water, and merchandising on both a cash and installment basis through 36 offices in the states of Oregon, Washington and Idaho with the principle office at Portland, Ore.

Type of Service	Number of Offices Serving
Electricity	28
Electricity and Gas	4
Electricity and Water	3
Electricity, Gas and Water	1

	Customers	Customers' Accounts
Total	66,504	58,164
Largest Office, Yakima	12,780	12,262
Smallest Office, White Salmon	512	403

All offices engage in merchandising. The number of installment accounts fluctuates widely between 5 and 40 per cent of the customers' accounts, depending on sales campaigns.

The types of rates on file for the various offices are as follows:

Block rates.

Load factor rates with block length varying with connected wattage.

Load factor rates with block length varying with number of rooms.

Load factor rates with block length varying with number of outlets.

Load factor rates with block length varying with maximum demand. (Power)

Flat rates.

There is an average of sixteen rates per office.

The following variations also apply:

5 per cent discount for prompt payment.
10 per cent discount for prompt payment (Gas)
5 per cent penalty for nonpayment within ten days.
One-half cent per kw-hr. discount for prompt payment.
Net.

From the foregoing picture it can be seen that although the total annual gross revenue of this company places it in Class "A", a Class "D" office routine is elaborate enough for its largest branch.

A congested period occurs once a month in each office as all bills and accounting reports are rendered as of the first of the month, therefore it has been necessary to build up the clerical and bookkeeping staff in each office to accommodate this peak. If the work which causes this peak should be gathered together in one central office and distributed throughout the month, a considerable saving in clerical hire could be effected.

If the branch accounting routine could be so simplified as to reduce it to the simplest kind of clerical work, it would be possible to employ in the smaller offices a different type of employe, an employe trained in merchandising, new business, complaint and repair activities. This would actually be a saving although it may not appear as an actual "payroll" saving. It is a false theory that because an employe is in an office, this or that additional work can be performed, or report prepared without additional cost. It may change the type or class of employe to be engaged and in time may become "the last straw that breaks the camel's back," and result in the employment of an additional person whose time would only be partially occupied.

These were the guiding thoughts in developing the following plan of customer billing and bookkeeping.

Operation of Stub Plan

The plan is essentially the stub plan. Rather it is an improvement on the stub plan in that it combines advantages of other plans with those of the stub plan and overcomes the usual objections to the latter, such as the difficulty in balancing in case of a lost stub, the low production in billing due to a long repeat print process, and the difficulty in segregating earnings by classes of service and by schedules where a company is rendering several classes of service under a great many tariffs.

A meter reading date has been fixed for each district office to permit continuous billing from the central office. District offices serving more than 3,000 meters and less than 6,000 have been assigned two meter reading dates. District offices serving more than 6,000 meters read continuously.

Each district office has been numbered, each meter reading book within a district office has been numbered and each service location within a meter book has been numbered. Example:

1—14—399 represents Bend, Oregon—book 14—service location or customer number 399.

All customer records in the district office are maintained in numerical order, and customers' applications for service cards are maintained in alphabetical order as an index to all other records.

Meter books after being read are forwarded to the Portland office, at least for the time being, by first class mail.

Portland office prepares:

The bill, ledger record and collection stub on a Burroughs machine. (Current charges for service only. One bill to a customer.)

A recapitulation sheet of all bills for each meter book with the customer service number opposite the first line of each bill. This recapitulation sheet is prepared in the process of billing.

A report of revenues by classes of service and by tariffs, by manually assorting and tabulating statistical stubs. The statistical stub is prepared in the process of billing.

A proof of billing.

Bills, ledger records, recapitulation sheets and meter books are then returned to the district office.

The district office enters with a fountain pen on the bills and through a carbon onto the ledger record:

Back balance for service.
Back balance for merchandise.
Current merchandise sales.
Installments due.
Total of all charges on each bill.

The recapitulation sheet for a meter book is then inserted in a wide carriage portable adding machines, the total of the bill is entered opposite the customer's number and these amounts are totaled at the foot of each recapitulation sheet. The total for the meter book thus determined is balanced with a control.

After proof, the bills are stripped from the ledger records and mailed in window envelopes which have previously been stamped with a U. S. mail permit stamp.

Ledger records with collection stub attached are filed in numerical order in the unpaid file.

As bills are paid, the cashier's stub is detached, dated and the amount received noted thereon.

Only one accounts receivable control account for a district office is maintained in the general ledger. This is a decided advantage. It is unnecessary to segregate cash collections by classes of service. It is unnecessary to detail amounts on cashier's stub. It permits one account for a customer and requires only one trial balance.

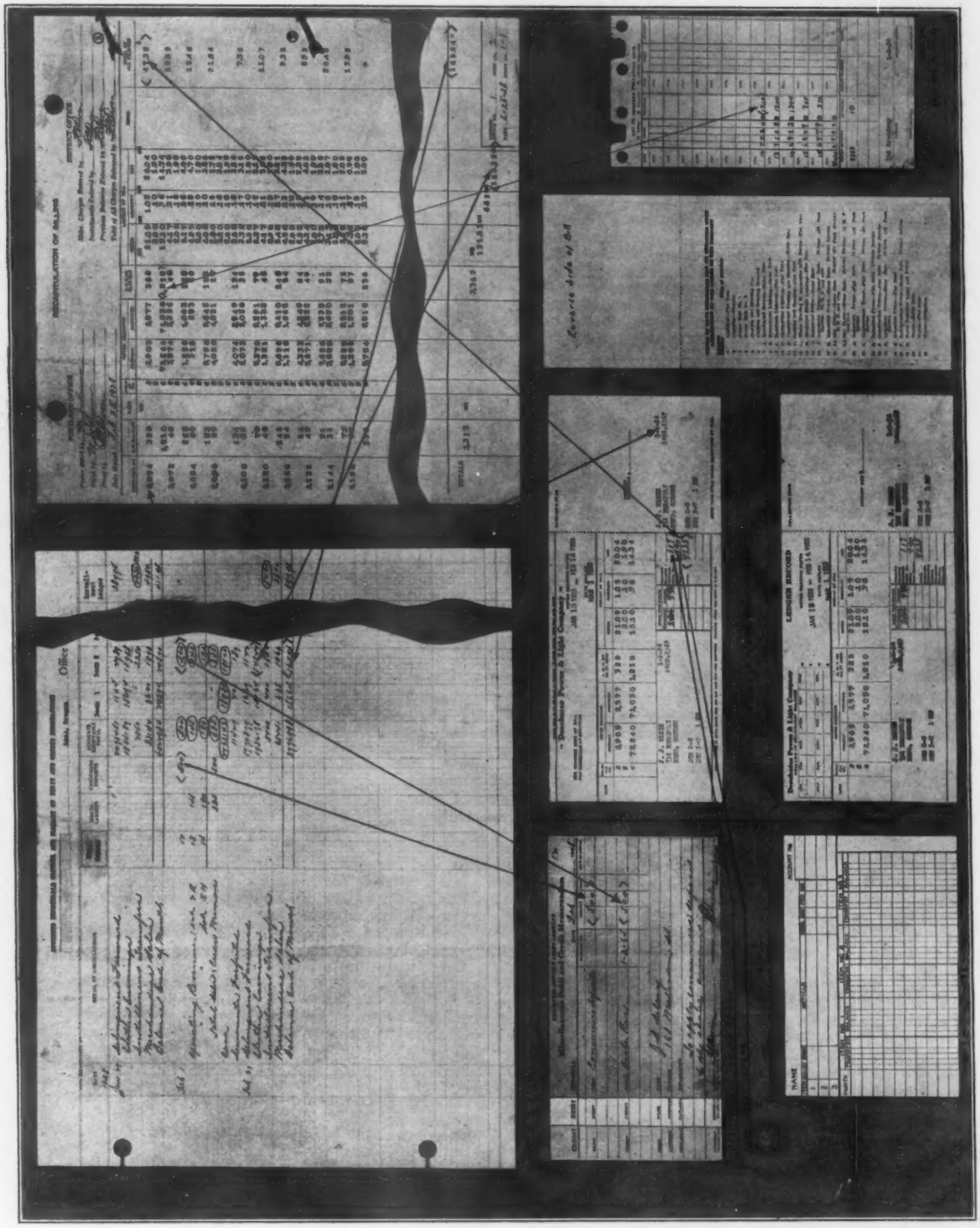
Cashier's stubs for the day are arranged in numerical order, listed and proven with cash collections.

After a careful study over a period of years it was decided that no advantage had been gained by using cash registers, therefore their use was discontinued. The advantages of a cash trap and rubber stamp are:

1. Two items to reconcile instead of three i.e. cash and stubs as against cash, stubs and register reading.

2. More flexible. In case of a rush, an additional cashier can step in with a tray of cash.

3. Saving in investment.



A daily report of cash collections is made to the Portland office.

Cashier's stubs are compared daily with ledger records and all paid ledger records are stamped paid, dated and filed in paid file. Partial payments are entered on ledger record in red ink and ledger record is returned to unpaid file. A cash credit memorandum is inserted in the unpaid file for all payments received for which there is no ledger record. This includes all pre-payments, payment of final bills and first payments on installment accounts.

Immediately after the discount date, forfeited discounts are added to unpaid ledger records and scheduled on a report to the Portland office.

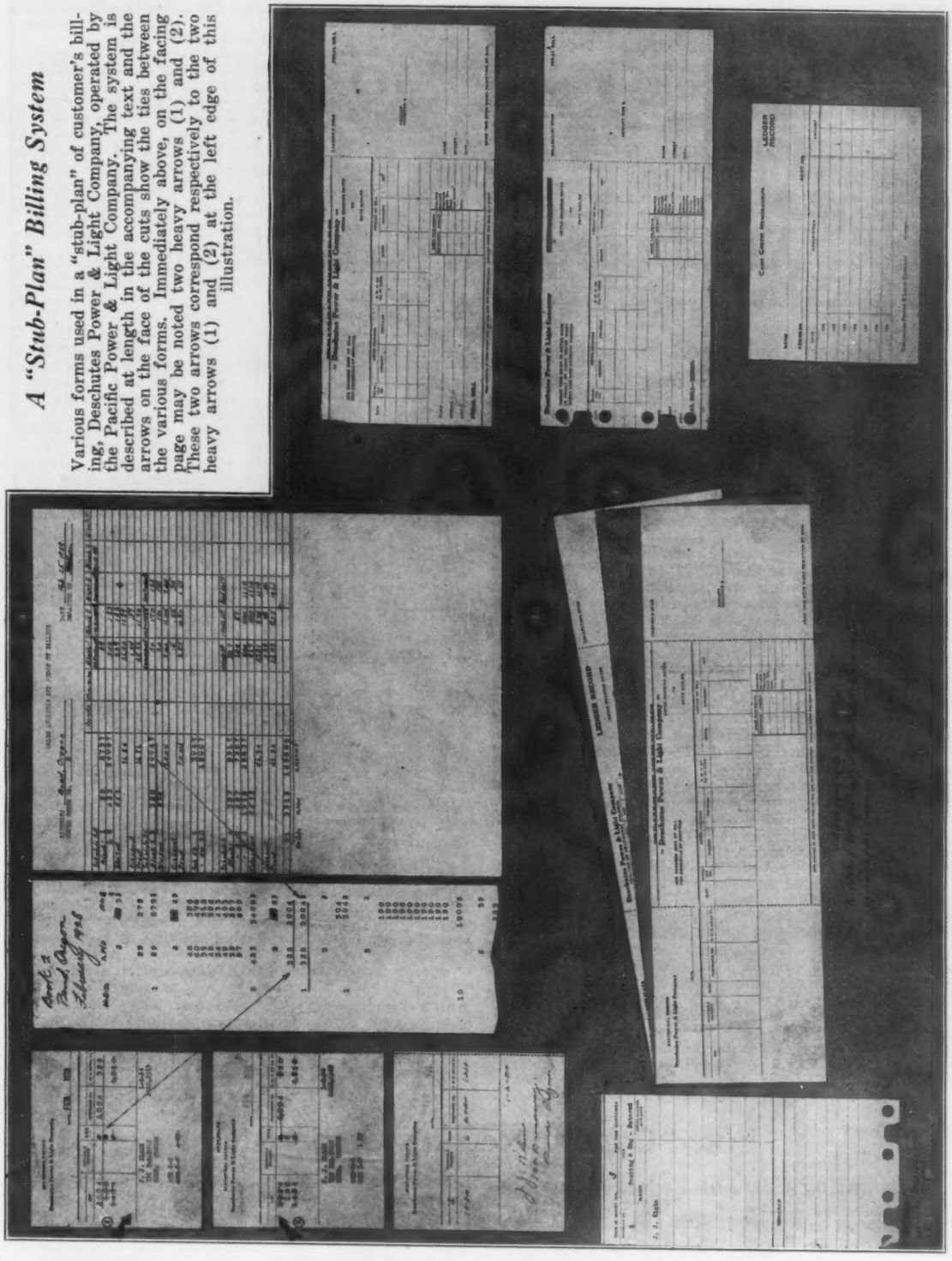
Net revenues are recorded on the books. As 80 per cent of all customers discount their service bills, it is less expensive to tabulate the discounts forfeited than to tabulate the discounts taken.

When unpaid items become delinquent the amount due is copied from the ledger record to the collection stub. The collection stub is detached, stapled to an appropriate reminder or notice to the customer and mailed in a window envelope.

Final bills are rendered in the district office. A copy of each final bill is inserted in the meter book in front of the meter index slip for that customer. Portland office takes up as revenue all such final bills by rebilling at the time of billing the meter book.

A "Stub-Plan" Billing System

Various forms used in a "stub-plan" of customer's billing, Deschutes Power & Light Company, operated by the Pacific Power & Light Company. The system is described at length in the accompanying text and the arrows on the face of the cuts show the ties between the various forms. Immediately above, on the facing page may be noted two heavy arrows (1) and (2). These two arrows correspond respectively to the two heavy arrows (1) and (2) at the left edge of this illustration.



The district office is provided with a debit and credit memorandum for:

Transferring accounts receivable amounts from one account number to another.

Applying customer's deposit to accounts receivable.

Crediting warrants or notes received from customers to accounts receivable.

Applying all allowances and adjustments to accounts receivable.

Entries between accounts receivable and reserve for doubtful accounts.

Any entry affecting accounts receivable.

A summary of debit and credit memorandums is reported monthly to Portland office.

In brief, the Portland office will be responsible for the mechanical process of billing and will compile all routine or special reports pertaining to customers' accounts, including rate studies, using the meter book as a source of information. Control of accounts receivable will be maintained in total only.

The district office will be responsible for the collection of customers' accounts, the balancing of consumers'

ledger records, adjusting disputed bills, maintaining of installment accounts and all detail transactions pertaining to the customer or individual accounts.

The advantages to be claimed for this plan are:

1. The ledger record is an absolute by-product. Not by a repeat print process but through a carbon.

2. The plan will permit the billing of as many classes of service on one bill as the width of the bill will permit, without complicating the segregation of revenues by classes of service or schedules.

3. Eliminates a thirty day merchandise ledger in that as the merchandise items are noted on the bill it carbonizes through to the ledger record.

4. All amounts due from the customer are recorded in one place.

5. When it is required to check over an account with a customer in the case of a register plan or a ledger plan the register or ledger is placed before the customer. The customer either does not understand the record which is before him or he is given the opportunity to compare his bill and date of payment with his neighbor's or the previous occupant's. This plan permits the presentation of a ledger record or ledger records for that customer only. What is more understandable to a customer than a copy of his bill?

Uniform Application for Opening Service Accounts

By M. J. Wilkinson*

It was brought to the attention of the Customers' Records Committee that a valuable service could be rendered by developing a uniform customers contract or application for service and at the same time produce better customer relations by simplifying the requirements of companies governing this application for service.

The results of the research disclosed that about 75 per cent of the total number of customers were residential customers while only approximately 30 per cent of the total revenue was received from this source, and further, that the losses due to uncollectible accounts for residential customers were much less than from any other class.

It would seem, because of the large number of customers involved that anything which would add to the convenience of the residential customer is worthy of the utmost consideration. We spend a considerable amount each year attempting to create a favorable impression with our customers. Obviously, we should remove any cause which would tend to offset this excellent "good will" work, especially so if this can be accomplished without sacrifice from any other standpoint. The companies are surely subjecting themselves to criticism by requiring the residential customers to appear at their offices and sign a contract each time service is required whether it is service at a different location or additional service at the same location, considering that the customer has previously requested service by filing a regular form of application, has placed on deposit with the company a sufficient sum of money to guarantee the final bill, and understands that the service will be discontinued if the current bills are not paid within a specified time, in accordance with the company's policy. The requirement of a contract with an established residential customer is of no benefit to the company from an operating or accounting viewpoint. At times it is expensive to obtain, especially so when requests for service are made by telephone which would require the writing of one or more letters or the sending of an employe to the customer's residence, or in some cases both. It is inconvenient and annoying to the customer if he is requested to come to the utility office.

* Report of customer records committee

Form 116

APPLICATION FOR OPENING SERVICE ACCOUNT

Pacific Power & Light Company (The Company) is hereby requested by the undersigned (the Customer) to open an account with the Customer on the Company's books to cover any and all public utility service which the Customer may take from the Company from time to time at any location or locations in any district served by the Company's plants or lines.

THE CUSTOMER EXPRESSLY RECOGNIZES THAT ALL SUCH SERVICE is to be supplied and taken SUBJECT TO the terms and provision of the Company's regular TARIFFS OF RATES, CHARGES, RULES AND REGULATIONS applicable thereto, as from time to time made effective. Copies of such tariffs are and will be available for the Customer's inspection at any time during office hours at any office of the Company.

Amount of deposit $ _____ Dated this _____ day of _____, 192__

Signed _____ _____ _____
Customer Address

Memo _____

NAME _____

CUSTOMER NUMBER	DATE CUT IN	ORDER	ADDRESS	DATE CUT OUT	ORDER

Fig. 1. Front and reverse sides of application record card used by the Pacific Power & Light Company.

It is the recommendation of your committee that a residential customer should not be required to sign a new contract or application each time a change in location is made or additional service applied for. In the case of a new customer, an interview is desirable. It affords an opportunity to acquaint the customer with the company and its business policies and the merchandise it has to sell, to fix the amount of deposit and to properly explain the reason for a deposit if deposits are required, and to obtain the customer's signature and thereby insure the correct spelling of his name on the records.

The accompanying form of "Application for Opening Service Account" is so worded as to cover any and all utility service which the customer may request from time to time at any location or locations served by the company. The reverse side of this form is designed to be used as a permanent alphabetical index card for the customers.

Fixed Capital Records Committee[2]

Accounting Costs of Federal Power Project

By J. A. Rockwood*

Introduction

The Oak Grove project of the Portland Electric Power Company was one of the first large hydro-electric projects to be constructed entirely under the jurisdiction of the Federal Power Commission. Because of the precedents established, the project has been of unusual interest. The accounting for the project has involved many unique questions, both on account of the relations with the Federal Power Commission and on account of conditions of the development.

For projects under the jurisdiction of the Federal Power Commission, four reports are required:

1. Cost of original project.
2. Annual report of additions and deductions.
3. Annual report of operations.
4. Statement of estimated depreciation requirements.

The Federal Water Power law provides that at the end of the license period, the government may elect to take over the project at a figure based on the cost of the original project plus the sum of the yearly additions and deductions, less the unused depreciation accruals. From the nature of the above reports, it must be very evident that the matter of accounting for projects under the jurisdiction of the Federal Power Commission is of prime importance to the companies concerned.

This paper deals with the accounting for the cost of

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* Report of fixed capital records committee

the original project, and the report to the Federal Power Commission.

Description of Project

The project is located in Clackamas County, Ore., and consists of a relatively small diversion dam by means of which the waters of the Oak Grove fork of the Clackamas River are diverted into a 9-ft. pipe line. The conduit is a riveted steel pipe line except for a small portion of the distance just below the intake, where it is reinforced concrete. The total length of the conduit is 6½ miles. The conduit passes through four tunnels and is supported by a number of steel bridges over the various creeks. It terminates in a surge tank at the top of Cripple Creek Knoll. Tunnels were driven through the Knoll to conduct the water to the penstock leading down the hill. The penstock has a total length of 1,284 ft., and terminates in a power house on the Clackamas River, in which is installed one 30,000-kva. unit. The effective head is about 860 ft. The outdoor terminal of the transmission line is located adjacent to the power house. The steel tower line begins at this transmission substation and follows a route down the Clackamas River to Estacada and thence via the interurban railway right-of-way, a total distance of some 50 miles to a switching station at Lents (a suburb of Portland). As this country was a virgin wilderness when the project was begun, with absolutely no roads or trails, it was necessary to construct a railroad from Cazadero to Intake, about 30 miles up a narrow canyon with necessarily heavy construction work.

In the accounting for the project, it was necessary to accomplish a number of objects:

1. Proper accounting for labor and material so that the company would secure value received for its expenditures.
2. The securing of the cost of each unit or structure in the project for valuation purposes and for Federal Power Commission requirements.
3. The supplying of unit costs of the operations concerned which are desired by the engineering department for purposes of estimates and checks.
4. The grouping of investment by property classifications as required by the Public Service Commission and Federal Power Commission.

The Oak Grove project cost between nine and ten million dollars and the accomplishment of the above results for a job of that size was quite a task in itself, especially in view of the fact that some of the objects desired were on untried ground, and, therefore, somewhat experimental.

Design of the Accounts

In order to accomplish the objects mentioned above, the expenditures were grouped under four heads:

1. Direct specific items, such as—dam, pipe lines, power house, etc.
2. Auxiliary operations, such as—sawmill, rock crusher, stores, etc.
3. Common expenses, such as—camp, tools, equipment, etc.
4. Overhead expenses.

These items will be taken up in that order.

Direct or Specific Items of Property

Under this head were included all the items of property which were constructed as a permanent part of this development. They were as follows:

Truck road
Railroad
Dam
Pipe line
Tunnels
Surge tank
Penstocks
Power house and substation
Hydraulic equipment
Electrical equipment
Transmission lines
Telephone lines
Operators' cottages
Miscellaneous construction

The above items represent the major divisions of the development. Each one of these items, of course, was composed of many smaller items, such as—bridges, real estate, foundations, etc.

Auxiliary Operations

Under this head was included a series of operations which were designed to cover the activities which would necessarily be closed out into the cost of certain units. For illustration, a sawmill was built and supplied lumber for many purposes. The cost of the plant necessary to handle the logs, cut them up and deliver the product, together with the cost of operating the plant, and other expenses involved in the process, make up the total cost of lumber furnished for the different uses.

The auxiliary operations were as follows:

Stores
Sawmill
Rock crusher
Transportation and terminal operation
Sale of logs

Common Accounts

In this class were grouped items which belonged to the specific cost of the units installed, but which could not readily be assigned until the completion of the job. Following are the items of this group:

Camp general expenses
Camp buildings
Camp equipment
Commissary and mess
Camp salvage
Construction telephones
Miscellaneous small tools—original cost
Miscellaneous—repairs and upkeep
Plant—original cost
Plant—repairs and upkeep
Plant—salvage

Overhead Accounts

Following are the expenses charged to the overhead accounts:

Consulting engineering
General engineering
General office administrative expense
Field superintendence and clerical
(Superintendent and immediate assistants)
Taxes during construction
Interest during construction
Hospital
Fire insurance
Liability insurance
Claim department expenses
Injuries and damages (persons and property)
Fees to the United States
Fees to the state
Contractors' fees
Legal
Forest service expenditures
Other overhead expenses

It is realized that this grouping of overhead expenditures is more or less arbitrary, but in the absence of an authoritative list of expenses that should be considered as overhead, no other course was available.

Construction Classification

How to provide for a construction classification that would be comparatively simple and yet supply all the required information was quite a problem. It is very desirable not to use more than three digits if possible because of the constant clerical work in writing these numbers, and in the danger of mistakes in the digits. It is also very desirable to give every possible aid in applying the system, such as letters that will naturally suggest the division intended, or numbers that are easily signficant of the operation or unit.

There are two systems that seem especially adapted to meeting these conditions. The first is the letter system. Applied to the conditions of the Oak Grove construction, the principal divisions were designated as follows:

Main Division	Significant Letter
Truck road	A
Railroad	R
Dam	D
Pipe line	P
Tunnels	N
Surge Tank	X
Penstocks	B
Power house and substation	K
Hydraulic equipment	H
Electrical equipment	E
Transmission lines	F
Telephone lines	L
Operators' cottages	O
Miscellaneous construction	M
Stores	S
Sawmill	W
Rock crusher	C
Transportation and terminal operations	T
Sale of logs	Z
General and Common	G

The second system is that of numbers. Applied to the general and common accounts, the designations were as follows:

General and Common

Overhead Accounts

1. Consulting engineering
2. Other engineering
3. General office administrative expenses
4. Field superintendence and clerical
5. Taxes during construction
6. Interest during construction
7. Hospital, equipment and operation
8. Fire insurance
9. Liability insurance
10. Claim department expenses
11. Injuries and damages
12. Fees to the United States
13. Fees to the state
14. Contractors' fees
15. Legal
16. Forest service expenditures
17. Other overhead expenses

Common Accounts

18. Camp general expenses
19. Camp buildings
20. Camp equipment
21. Camp salvage
22. Construction telephones
23. Miscellaneous small tools—original cost
24. Miscellaneous—repairs and upkeep
25. Plant—original cost
26. Plant—repairs and upkeep
27. Plant—salvage

If it is desired to apply any of these items to any specific construction, as for illustration engineering on the dam, it can be done easily by attaching the number to the letter indicating the main division. In the case of engineering on the dam, the charge would be D-2. Plant used entirely for construction of penstocks would be B-25. The system is very elastic and enables a maximum of combinations with a minimum of digits, and yet is simple.

For the classifications of the operations used in the specific construction, numbers from 30 to 100 can be used for each main division. Seventy numbers will ordinarily supply all the subdivisions desired for any one main division, and if any additional numbers are required an additional digit can be used. The purpose of the classification is to supply all the combinations needed with the smallest number of digits, and yet in as simple a manner as possible. The above system provides for all the classification necessary with one letter and two digits and is simple in application.

It might be of interest to discuss some of the details of the above divisions.

Direct or Specific Items

These items include the direct or specific items of property, such as—dams, pipe lines, etc. It all depends upon the conditions of the individual case as to how the classification is worked out. In general, it should be in terms of the physical units of property that would be found if an appraisal of the completed property were to be made. For illustration, the pipe line consisted of:

1. The pipe of many different thicknesses due to varying heads.
2. The bridges and structures supporting the pipe.
3. The clearing of the land.
4. The excavation of the subgrade and backfill.
5. The anchors.
6. The special structures in the pipe such as manholes, air vents, etc.
7. Valves.
8. Drainage.

One each bridge there is excavation, concrete, steelwork, etc., with corresponding quantities of cubic yards, pounds of steel, etc. The accounts should be so designed that the total cost of each bridge or structure can be easily secured in suitable detail with the corresponding quantities and unit costs. These classifications should be worked out in connection with the engineers' plan. An understanding in detail of what is to be done is a prime essential in the design of a classification of accounts.

Each main subdivision must be worked out in form suitable to that subdivision.

Auxiliary Operations

It is comparatively easy to outline the direct or specific items, but it is more difficult to handle the auxiliary operations. For that reason it may not be amiss to discuss some of these operations which will be illustrative of the class.

Stores—One of the most important questions is the treatment of "Stores." In general, the best plan seemed to be that of handling all purchased material through the Stores Account and charging it out of that account to the account involved. Only in that way could the proper safeguards be put around the protection of the materials and proper charges be made to the account benefited. These expenses of handling stores, such as the cost of purchasing, handling, records, insurance, etc., were closed out periodically on a percentage basis in the same way as the materials themselves were charged.

Sawmills and Rock Crushers—These operations are typical of a number of this character. These plants are used to manufacture materials used in the construction of units of property. The cost of the lumber or cubic yards of crushed rock produced involves the purchase of plant, the setting up of the plant, the securing of the raw materials, the operation of the plant, the repairs of the plant, and eventually the salvage on the plant. In the end the total cost of these operations was cleared out by proper charges per thousand feet of lumber or cubic yards of rock or other suitable units to the account on which the material was used.

Transportation—In a development involving widely scattered operations such as most hydraulic power projects are, the matter of transportation is one of prime importance. Consequently, the accounting for the cost of transportation is of corresponding importance. On the Oak Grove project 30 miles of railway were built purely for the construction and operation of the project. Following are some of the elements of cost that entered into the total cost of transportation on this project:

1. Terminal operation
2. Dispatching
3. Superintendence
4. Wages of engine crews
5. Fuel, oil, etc.
6. Rental of equipment
7. Repairs to equipment
8. Maintenance of way and structures
9. Speeder operations
10. Automobile operation
11. Garage expense
12. Stable expense
13. Upkeep of wagons and equipment
14. Upkeep of roads during construction
15. Miscellaneous transportation expense

With such a variety of operations, there is necessarily a wide variety of methods that can be used in handling them. The experience on this project led to the adoption of the method of keeping all of the above expenditures under suitable accounts, but not distributing them until the completion of the job. However, it was necessary to compile, as the job was being done, all the necessary data for the assignment of those expenses upon the completion of the job. In general, the ton mile seemed to be the best unit to use for the distribution of the transportation expenses. The ton miles must be secured from the waybills as they go through, otherwise it is well nigh impossible to secure the information.

Overhead Accounts

1. **Consulting Engineering**—No special comments on this heading.
2. **Other Engineering**—This included all other engineering, such as—supervisory, office, field, etc. Under the system above outlined, the general engineering was charged under "G," while the engineering on any special division was charged to that division. For illustration, engineering plans on the power house were charged to "K-2." Instrument parties on the pipe line were charged to "P-2." This is a refinement that in a large job enables closed apportionment to the division involved.
3. **General Office Administrative Expense**—This covers the proportion of the administrative expense that belongs to construction work. On this project it was handled on a percentage basis and was charged out directly in proportion to the construction expenditures.
4. **Field Superintendence and Clerical**—Items of superintendence under this account were limited to those applying to the whole job. Sub-foremen and those involving certain operations only were charged to the specific accounts.
5. **Taxes During Construction**—The only suggestion on this subject is to be sure that any taxes applying to work in progress are actually charged to the construction work instead of to the operating accounts.
6. **Interest During Construction**—This is an important question both on account of the size of the item and on account of lack of uniformity in handling. A more detailed discussion may be of interest.

   Only in exceptional cases can the funds for construction purposes be segregated from the general funds of the company. Consequently, it was not practicable to assign directly the interest on any specific bonds or stock to any specific construction job. Therefore, it was necessary to estimate the amount of interest applicable to construction work. In general the gauge of the amount of interest is the going cost of money.

In the case of the Oak Grove development 6 per cent interest was used in computing the interest on the expenditures during the preliminary period before actual construction started. Eight per cent was used during the period of high money cost in the years following the end of the war, and 7 per cent was used when money became easier.

In this connection it should be noted that the interest rate included not only the actual interest paid, but also the cost of raising the money, properly spread over the life of the issue.

7. **Hospital Equipment and Operation**—This is self-explanatory.
8. **Fire Insurance**—This is also self-explanatory.
9. **Liability Insurance**—This covers the cost of liability insurance whether carried by the construction company or through the state Industrial Accident Commission. In either case it is a function of the payroll.
10. **Claim Department Expenses**
11. **Injuries and Damages**—Care was taken to see that the proper part of the cost of maintaining the Claim Department applicable to the construction work was charged to the construction work. Also, that the cost of the settlements the Claim Department made was charged to the construction work instead of to operating accounts.
12. **Fees to the United States**—This item is applicable only to the projects under the jurisdiction of the Federal Power Commission.
13. **Fees to the State**—In most states annual fees are levied by the state on the water used in hydraulic developments in proportion to the horsepower utilized. This item covers such fees during the period of construction.
14. **Contractors' Fees**—No special comment about this item.
15. **Legal**—There is always a difficulty in determining the proportion of the legal expenses that belongs to any particular construction work, but it should not be passed over because of that difficulty. The most satisfactory means for determining this amount seemed to be the proportion of the Legal Department's or an individual's time that was given to the special development to the total time of the department or individual.
16. **Forest Service Expenditures**—In developments under the jurisdiction of the Federal Power Commission there are many expenditures required by the Forest Service, such as—fire fighting, transportation, camps, telephones, etc., which are in the nature of an overhead, and which in the Oak Grove Project were kept under the above heading.
17. **Other Overhead Expenses**—This is self-explanatory.

Common Accounts

There are a number of accounts which might be classed as overheads, but which in the case of the Oak Grove development were considered as common accounts and distributed as a part of the specific expenses before the overheads were assigned. This group includes "Camp General Expenses," "Camp Buildings," "Camp Equipment," and "Camp Salvage." These expenses are a function of the labor and were, therefore, assigned directly in proportion to the labor.

"Construction Telephones" were clearly segregated from the permanent telephone equipment.

The Construction Plant items were kept in detail sufficient to allow reasonable assignment at the end of the job. The scheme of accounts described in the earlier part of the paper was very elastic and was easily adapted to meet the requirements of any special condition.

The advantages of assignment of the plant accounts at the end of the job are:

1. Simplicity. Only one assignment instead of many.
2. All the information is available at the end of the job, when during the period of construction much of it is lacking.
3. No adjustments are necessary.

Another method is to charge plant rental to the operation involved as the equipment is used on these operations. A common rental charge for equipment used in this way is 2 per cent a month. A very clear description of this method is contained in the tenth volume of the report of the Miami Conservancy District, dealing with construction plant, methods and cost, pages 19-22. The advantage of the plant rental method is that it makes possible a closer check on the cost of the different operations as the work progresses. Also the distribution is made when the principal facts are fresh in the minds of all concerned. In practically all cases an adjustment is necessary.

Whichever method is used, a card record should be made of each piece of equipment showing nameplate data, identifying numbers, history of the apparatus, including cost, freight, etc.

Co-ordination of Estimates and Cost Reports

It is a matter of a good deal of importance that the estimates of the cost of a job should be made up in the same form as the monthly progress cost reports. Both estimates and cost reports should be so designed that a ready comparison can be made in detail between the actual cost to date and the estimated cost. In a large construction job the engineers naturally desire to know how the actual cost is comparing with the estimated cost, and the only way in which a comparison of any value can be secured is by a comparison of similar items. For that reason attention should be given to see that the cost reports be made up in such a form so that ready comparison may be made with the estimated cost.

Project Accounting

In order properly to safeguard the company's interest in the construction of a big project and in order to secure the greatest benefit from the expenditures, suitable methods must be followed. The experience on the Oak Grove suggests emphasis on the following points:

1. An effective system for handling purchases and supplies. Especially on a project with operations scattered over a large territory, the proper protection of materials and the correct accounting for these is a very important matter and is worthy of the most careful thought. With a large construction force it is unavoidable that there will be some who will seek to use company materials for their own purposes. It is also a difficult matter many times to charge materials to the proper construction account. The same safeguards are needed around the stores of a construction job as are used for the usual stores in a company's operation.
2. Accounting for the project in the field has very decided advantages over accounting for the project in the general office. The general office is too far removed from the scene of operations. Conditions in the field change so rapidly that it is impossible for the general office to keep up with them. It is imperative that the accountant in charge be closely in touch with these changing conditions in order to have the information for the correct handling of the accounts.
3. Accounting for the project centralized in the hands of one individual who can be responsible for all the accounting on the project has many advantages. Division of responsibility does not lend itself to a satisfactory handling of the questions that come up. The accountant should have not only a thorough understanding of good accounting, but should also have an appreciation of the physical structures and conditions so that he will understand somewhat the engineers' viewpoint, especially in accounting for units of property and in the use of unit costs.
4. The distribution of labor entirely under the control of the accountant for the project works more satisfactorily than when responsibility is divided. The accountant should be closely enough in touch with the work to know that the classification is being carried out and that the charges are properly made. The classification should be as simple as possible and not too much in detail. It is better to estimate subdivisions than it is to attempt too great refinement.
5. As few radical changes as possible should be made in the accounting system during the period of construction work. Every radical change means confusion and difficulty and should be avoided.

Report of the Cost of Construction

The regulations of the Federal Power Commission provide that on the completion of a project the licensee shall render a report of the cost of such project in such detail as the commission may ask, even to the extent of a voucher record. The commission, however, has indicated the desirability of a report of the cost by items of property in place with all overheads assigned to these units so that when retirements are made the figures would be available without any further assignment. Inasmuch as this seemed to be a desirable object to be attained on the part of the company, it was determined to try out the plan in the case of the Oak Grove project. The classification of accounts was arranged with this end in view, and provision was made for the grouping of accounts so that combinations could easily be made to produce the results desired.

When the active construction work was finished, the ledger accounts were gone over for the correction of any apparent errors of distribution. Then the process of consolidation began with the closing out of the supplementary operations, such as rock crusher, sawmill, etc. These were closed out into the account for which the work was performed and distributed on the suitable unit basis, such as—cu. yd. for the rock crusher and thousand ft. of lumber for the sawmill. The cost of the transportation was consolidated and distributed in proportion to the ton miles. The stores accounts were closed out and adjusted.

The next step was the clearing out of the common accounts. The camp expenses were assigned in accordance with the labor, inasmuch as the camp expense is due practically entirely to the labor. Plant was assigned directly to the operations involved as far as practicable, the balance in proportion to the total expense. Likewise, the rest of the common expenses were assigned in proportion to the total expense.

Assignment of Overhead Expenses

The assignment of the overhead expenses was handled in the following manner:

1. The overhead expenses applying to any special group were segregated and assigned to that group. For illustration, the engineering expenses directly concerned with the pipe line were assigned to the pipe line. The cost of making the plans for the power house was charged to the power house. That is, all the overhead expenses applying to any one main group were assigned to that group.

Next the expenses that were common were collected under five groups as follows:

Group 1. General overhead expenses to be distributed on basis of labor expenditures
Liability insurance

Group 2. Accidents to persons
Damages to property
Hospital
Field engineering
Office engineering
Field superintendence
Field clerical
Other overhead expenses
Contractors' fees

Group 3. Expense of claim department
Legal expenses
Taxes during construction
General office expense
Organization expense
Construction telephones
United States Forestry telephones
United States Forestry camp sites
United States Forestry trails
Unclaimed wages

Group 4. Consulting engineering

Group 5. Interest during construction

Items 2, 3 and 4 in general were distributed in proportion to the total expenditures, but on account of local conditions there was a difference in their application; hence, the reason for keeping them separate.

The distribution of Item 5 may be of interest. The expenditures on each main division of the development were determined month by month up to the time the project was put into operation. From these figures the dollar months of expenditure were computed. The total interest then was assigned to each main division in proportion to the dollar months applicable to that division. Within that division the interest was assigned to the different units of property in the same way as the rest of the overheads in that division, in proportion to the total expenditure. Under the conditions of the Oak Grove project it was found that the application of the above methods resulted in very different percentages of overhead on the different divisions of the work. For illustration, the railroad of necessity was the first item to be constructed. Interest on these expenditures was necessary for a period of three years. Hydraulic and electrical equipment which was installed in the year prior to the beginning of operation naturally received less than one year's interest. On this account the overhead percentages on the different parts of the property varied all the way from 15 to 35 per cent. The average on the entire project was about 28 per cent.

Units of Property

The result of these consolidations was the tabulation of a large number of units of property, showing not only the cost as a whole but the cost of details, and the description of the property. For illustration, an operator's cottage consisted of the cost of excavation, concrete, frame structure, lighting fixtures, furnishings, etc. A steel bridge supporting the pipe line included the excavation of so many cu.-yds. of dirt at so much per cubic-yard, so many yards of concrete, so many kinds of reinforcing, so many pounds of steel in the bridge proper, with suitable information regarding the cost of erection and painting, all together making up the cost of the bridge. With the cost figures on these units, there was also given a suitable description of the unit with location on the maps which were submitted to the Federal Power Commission. In addition, reference was made to the drawings and blueprints of the structures on file in the Engineering Department. The underlying idea was to record permanently as much of the essential information regarding these units as possible. Otherwise, the information is lost, and when such information is desired in the future it is almost impossible to secure it.

Consolidation into Report

After the units of property were secured, the next step was the combination of these units in accordance with Federal Power Commission classification of accounts. This is an easy matter, as an understanding of the use to which the unit of property is put determines the suitable property account. Under each property account were the units of property arranged in an orderly manner with all the information available in one place concerning that unit.

Fixed Capital Records in Relation to This Report

The compilation of this report has brought out clearly the essentials of good fixed capital records. Good fixed capital records involve the following:

1. Cost of completed unit with all overheads assigned.
2. Description of that unit with reference to plans where necessary.
3. Unit costs and quantities involved in details of that unit.
4. Location with reference to maps where practicable.
5. Property account to which charged.
6. Authorization number and date of installation.

Conclusion

The use of the above methods on the Oak Grove project resulted in a report that seems satisfactory both to the company and to the commission. It puts in workable shape the information both the commission and company need to have. In case of property retired, the information is immediately available as to the value to be retired. In case of insurance, the cost of any unit is definite, either for taking out of insurance or for settling a loss. In establishing the value of the additions to the rate base, it is possible to prove cost of any structure or item. In supplying information about location, specification, or history, the report supplies a great mass of information. In other words, it is the aim that it shall meet the needs of the best standards of fixed capital records.

The Federal Power Commission has not issued any specific instructions as to the amount of detail required in the cost reports of the projects under its jurisdiction. The officials of the commission, however, have indicated the desirability of a report by units of property. As a result of the experience in the accounting for the Oak Grove project, those who have had to do with this accounting have come to the conclusion that the time used for setting up the original cost of the project in an orderly manner by units of property will be saved many times over before the expiration of the license. The difference in the cost between the minimum that would be required in reporting a project, and what it did cost to set up the details completely and in order, was insignificant compared to the total cost of the project.

Purchasing and Storeroom Committee[2]

Purchasing Department Methods

By A. D. Smith*

The purchasing and storeroom committee has held two meetings in Salt Lake City during the association year. The committee decided as its first work this year to prepare a discussion of purchasing methods and purchasing department records. The following outline of purchasing department methods and records was prepared by A. D. Smith, vice-chairman of the committee and purchasing agent for the Utah Power & Light Company. This paper is a general outline of purchasing department methods rather than a particular description of the method followed by one company, and in view of this fact specific mention of particular forms was omitted as we find a great similarity in the forms as used by various companies which we have investigated.

The function of the purchasing department is largely one of service to other departments, particularly the construction, operating and sales department, and it is essential that its methods and records be such as will best meet the requirements of these departments as

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* Report of purchasing and storeroom committee

well as all other departments requiring materials and supplies. Close co-operation is necessary to the end that the purchasing department be promptly advised when and where materials will be required and in what quantity so that the various quantities may be combined and purchases made to the best advantage. After orders are placed it is essential that the departments interested in the purchases be promptly advised of action taken by the department, and its methods and forms have been developed, we believe, so as to accomplish this result with a minimum of effort and expense.

The Requisition

The requisition form, which is the basis of the purchasing department's activities, is one of the most important forms and it is essential that it contain complete, concise and accurate information as to the material required by the various other departments. It is also important that each requisition be confined to material of a given classification since in most purchasing departments the work is segregated, one employee buying a certain class of material, such as electrical appliances; another buying hardware, etc., thus concentrating the handling of orders for each class of material under the supervision of an employee who becomes expert in that particular line. If this segregation is not followed the placing of orders is necessarily delayed while the employee handling the buying of one kind of material is completing his work before turning the requisition over for the purchase of the other kinds of material. Before the requisition is turned over to the stenographer for typing of the order, it should bear notations covering all salient facts, including name of the firm, the order number, prices covering each item, the promised delivery, the discounts agreed upon, including cash discount, routing, if the shipment is to move via freight, and the f.o.b. point.

Inasmuch as requisitions originate at a great many different points, it is impossible to issue them in numerical order. This results in considerable difficulty in filing requisitions in such a way as to make it easy to refer to them. This difficulty has in part been overcome by filing of requisitions received during each month, the numbers of which end in one, in date order and following through the other numerals. Nothing is filed with the requisitions, correspondence, specifications, etc., referred to in the requisitions, if any, being filed elsewhere. The requisition is stamped when received by the purchasing department and the date the order is placed is noted on same so that any delay in the department may easily be checked.

The Purchase Order

The order form is printed in sets of six including the original and when written up shows the order number, sets forth a full description of material wanted, prices and discounts agreed upon, the delivery promised, routing instructions, including instructions as to minimum weights to be observed in the case of orders covering several carloads, thus preventing loss of freight charges due to overloading, instructions as to invoicing by the firms from which purchases are made, and lists those to whom copies of the order should be sent, which includes the person or department issuing the requisition and all others who may be interested. This automatically advises those interested as to date of placing the order, prices involved, delivery to be expected and eliminates a vast amount of correspondence which would otherwise be entailed.

One copy is placed on the regular purchasing department correspondence and order file of the firm involved and another copy is placed on an alphabetical arch file which is the working copy of each employee handling the details of an order. This copy remains in the arch file until the invoice has been received and has been checked against the order, after which it is placed numerically in a permanent finished order file. This copy bears notations showing partial and complete shipments including dates, prices, exceptions, etc., and constitutes almost a complete history of the transaction. In actual practice it is found that it is seldom necessary to refer to any other document than this record. It is the rule that no invoices shall be checked on any other copy of the order and when observed, duplicate checking and passing of invoices to accounting department for payment is impossible. Strict observance of this system of checking invoices is an important element in purchasing department routine.

The retention of an incompleted or working copy of all unfilled orders on the desk of each purchasing department buyer charged with the responsibility of securing agreed deliveries has proved to be an effective means of securing a close "follow-up" of unfilled orders. Each employee is instructed to look over his unfilled order file frequently and to trace either by phone or mail with respect to orders not filled within the agreed time as evidenced by failure to receive invoices and bills of lading. To reduce stenographic work a printed tracer form is used with request for immediate advice. Another printed form is used in returning invoices for correction of common errors and ommissions. The use of these forms probably reduces correspondence fully 50 per cent.

Another order form is used in ordering material from the general warehouse of the company to be delivered or shipped to local or other divisions, the routine in this case being practically the same as the regular order form.

The Sale Order

The purchasing department is charged with the responsibility of selling obsolete and excess apparatus, as well as all scrap materials. To cover such sales, a sale order is issued on the department in charge of the material, describing same, advising to whom the material is to be delivered, and the price agreed upon. A copy of this sale order is sent to the accounting department so that invoices may be rendered and collections made in case of credit sales. However, about 90 per cent of all such sales are spot cash sales, or in case of shipment to distant points, collections are made by means of sight draft against bill of lading.

In order to reduce correspondence, a "Bid Sheet" is used for the purpose of requesting prices and in connection with this, a sheet is used for the tabulation of of quotations which facilitates the anaysis of propositions from various firms.

Since it is important that stocks not only at the general warehouse, but at all other points on the system be kept down to a minimum, consistent with efficient service to the industry, it is necessary that from time to time reports of excess or obsolete stock be received and tabulated so that it may be used to fill requisitions and shipped to points where needed, or sold in case of obsolescence.

Claims

Most purchasing departments not only handle the routing of shipments of material as purchased, but also handle claims against transportation companies for damage to shipments enroute and for rate overcharges. For this purpose two forms are used, one applicable to "loss and damage" claims and the other to rate overcharges. After preparation and submission of claims, they are followed through to collection. A copy of each claim is sent to the accounting department so that a charge may be made against the transportation company involved. In addition to this record in the accounting department, a copy of the claim is filed on the regular file of the railroad, express or trucking company and in addition a record is kept in a bound book showing the number of the claim, the amount, whether for loss and damage or for overcharge and finally the amount collected, including interest in case any should accrue.

Prices

In order that information with respect to prices may be readily available, a card index file of commodities is kept showing the date of purchase, firm name, quantity, description of the item and the price. This card index contains only changes in prices, duplicate purchases without price change being disregarded, except in the case of items infrequently purchased.

Replenishing Stock

The general warehouse record is handled by means of a continual inventory card form, by means of which the storekeeper can tell almost immediately the stock of each item on hand. From this continual inventory form can readily be obtained the rate of use of each item. In connection with this a "Report of Low Stock" form is used by the storekeeper for the purpose of informing the purchasing department when the minimum allowed has been reached and of the amount still in stock. The card covering each item bears a notation of the established minimum. When this minimum is reached the storekeeper reports on form above mentioned and requisition is issued covering the refilling of stock.

Filing and Routing of Forms

The card index numerical filing system is used with correspondence, orders, etc., each firm's correspondence being filed in chronological order. Cross indexing of subjects is used. This system is very simple and it has been found in practice that complete information on any subject can be secured by means of it within from three to five minutes.

As outlined above in the paragraph relative to order forms, the original copy of the order is sent to the party from whom the purchase is made, two copies remain in the purchasing department for filing and for tracing purposes, the fourth copy is sent to the general accounting department and the fifth and sixth copies are distributed to the storeroom, division office or other department where the material is received and where the requisiton for the material originated. The copy received by the general accounting department is placed in numerical order for convenience in checking invoices.

Invoices

All invoices when first received are sent to the purchasing department where they are checked as to price, delivery and any special features which may be covered by the agreement to purchase. After such check is made, the invoices are forwarded to the general accounting department where they are again checked with the order and the extensions verified. The invoices are registered in the accounting department and forwarded to the department for whom the material was furnished and by whom the material has been received. This department, which also has a copy of the order, checks the invoice with the report of material received which is prepared for the receipt of all material, to ascertain that the quantity of material received agrees with the invoice. If the material received is correct as ordered and is in good condition, the invoice is approved as to the receipt of the material by department in which material is received and is also approved by the head of the department for payment. The invoice is then returned to the accounting department where it is marked "returned" on the invoice register and placed in line for payment through "Accounts Payable."

Various forms of invoice register are used by different companies, but the form most generally used is one in which the invoice register is used as the name implies with no endeavor to make it a part of the general accounting system of the company. Such a register invoices the registering of the date, name and amount shown on the invoice and the date and name of the party to whom it is transmitted for approval and an additional column for the date the invoice is returned to the general accounting department.

Saving Discounts

In the first paragraph of this discussion, the importance of co-operation between various departments and the purchasing department was briefly outlined so as to show its importance in connection with the purchasing of material in economic quantities to obtain the best price and also the best and most economical method of delivery. It is also important that the same co-operation be exercised between the purchasing department and the accounting department and also all the other departments of the company where purchasing department requisitions originate so that the payment for materials purchased may be made with the least possible delay, thus avoiding the loss of discounts allowed for prompt payment. Prompt payment discounts which generally vary from 1 per cent to 5 per cent during the period of ten days represent a large rate of return on the amount of money involved and it is important that a company take advantage of all cash discounts. This condition may only be obtained, especially in a large company where many departments are involved, by the closest co-operation of the work of the purchasing department with the accounting department and all the other departments of the company. Such co-operation can only be obtained through the establishment of simple routine, thus avoiding correspondence between departments and a consequential loss of time. In addition to the actual loss of money to a company through loss of cash discount, the simplification of a system of purchasing and the resulting accounting on invoices for material purchased is important as it facilitates the labor of accounting in practically all branches of accounting work.

General Records Committee[2]

General Ledger Controlling Accounts*

The group arrangement of committee members, followed this year, made readily accessible the majority members of our committee so that it was possible to discuss without serious delay matters of importance relating to committee work.

The committee confined its efforts to co-operation with the national body, and stood ready to take up such matters as were referred to it by member companies within the scope of the yearly program.

A paper was prepared on "General Ledger Controlling Accounts," which paper is the main contribution of the committee this year. There may be doubt in the minds of some regarding the value of a paper on this topic. It may be argued that the field is too limited to be productive of worthwhile results, and yet when we analyze the mass of matter set up in many general ledgers with their multiplicity of duplications, the need for ledger control is quite apparent. The paper was prepared with the idea of setting our membership to thinking seriously of general ledger contents, and to suggest that it is not essential they contain many items they now do. If that has been accomplished your committee is amply rewarded.

General Ledger Controlling Accounts

A controlling account may be defined as one which shows in total details found in a subsidiary record.

The use of such accounts is not limited to public utility accounting. Hardly any business is so small but that it is found necessary to use separate records at least for recording the details of cash and customers' accounts. In a larger business it may be found necessary to use a great number of subsidiary books in order to keep a detailed record which could not possibly be carried in the general ledger.

The chief reasons for the use of controlling accounts are:

1. The general ledger should be a complete record of the transactions of a business in a condensed form. While the question as to whether or not a controlling account would be an advantage can be determined only by a study of the requirements of each individual enterprise, it may be stated that when the accounts become so numerous that they cannot conveniently be carried in one book, controlling accounts should be used for such classes of accounts as are most numerous and the details should be carried in subsidiary records.

It is obvious that a ledger limited to balance sheet accounts solely is an ideal arrangements from the standpoint of a balance sheet preparation in that it is not encumbered with a mass of detail accounts, but contains only those accounts required properly to reflect the condition of the business. For a large organization engaged in various operations, such an arrangement may be found necessary.

2. It saves time and labor in taking off a trial balance. With a small number of accounts, errors are less frequent and can be located much more readily.

3. By the use of controlling accounts a complete balance sheet may be prepared before posting the details to the subsidiary records.

4. It permits the work to be distributed among various clerks, and each clerk is still enabled to prove his own work independently of the others.

We will now consider briefly those accounts where controlling accounts may ordinarily be used to advantage.

Fixed Capital Accounts

The detail of the investment in fixed capital does not belong in the general ledger. A utility company may, however, not confine its business to one class of operations. An electric utility company may be engaged also in street railway, water, or some other class of operation. In such a case accounts should be provided in the general ledger for each class of operation in which the company is engaged. Also, it frequently happens that property is acquired by a company for which it has no immediate use. Such an investment cannot be in-

[2] **A. J. Johnstone**, Portland Electric Power Company, chairman. **Northwestern Electric Company:** J. G. Hawkins. **Pacific Power & Light Company:** G. F. Mackenzie. **Portland Electric Power Company:** E. I. Snyder, vice-chairman. **Puget Sound Power & Light Company:** C. F. Kirchaine.

* Report of general records committee

cluded in operating property, but must be carried in a separate account.

The question as to what records should be kept to show the detail of the investment in fixed capital will not be here discussed as that is left to the fixed capital committee.

Cash

As a general rule one account in the general ledger is all that is necessary under this caption. At the end of each month the total of cash receipts as shown by the cash book is debited to this account and the total disbursements credited. The accounts with banks are carried in the cash book. If the number of banks is not too many, it is only necessary to provide columns in the cash book both under receipts and disbursements for each bank. As money is deposited or checks issued the item is entered in the column provided for that particular bank.

Notes Receivable

While it may not be found necessary to carry more than one account under this caption the detail required cannot all be shown in the general ledger. It is necessary to keep a subsidiary record showing date of note, maker, amount, interest rate, date due and payments received on account.

Accounts Receivable

No definite statement can be made as to what accounts should be carried in the general ledger under this caption. It should, however, be borne in mind that the general ledger should not be overloaded with unnecessary detail.

Where a company engages in more than one class of operation separate accounts should be provided. Also, where business is carried on in a number of cities or towns and the customers' accounts are not carried in the general office, a separate account should be maintained, either in the general ledger, or, if there are a number of local offices, through the use of a subsidiary record.

Material and Supplies

The records in the general office should show the money value of the stock carried in each storeroom. Where the operations of a company cover a large field and it is necessary to carry a stock of material at many locations, the general ledger can be confined to one account and the detail carried in a subsidiary record.

Prepayments

The items most frequently found under this heading are for insurance premiums, taxes and rents. It is needless to say that when an insurance policy is taken out to cover a period usually for one or three years the amount of the premium paid should not be charged to operating expenses in one amount, but should be taken up in equal monthly installments over the life of the policy. In order to do this some record must be kept outside the general ledger.

A very convenient method is to use a columnar record. This record should be arranged to show the date of policy, policy number, name of insurance company, amount of policy, property insured, and amount of premium paid. The months of the year are entered in the columns across the top of the page. The proportion of the premium applying to each month then being entered in the columns across the page. After all policies have been entered it is then only necessary to total the different columns to get the amount to be charged to operating expenses in any one month. The balance not charged off as shown by the insurance register must, of course, check with the general ledger balance.

Where a company is engaged in more than one class of operation separate pages should be used in the register. There would, however, be nothing gained by dividing the account in the general ledger.

The method used to distribute insurance premiums will also apply to taxes, license fees, rents, and other items paid in advance for a definite period.

Subscribers to Capital Stock

This account has come into use within the last few years, largely by reason of the companies' seeking to interest customers financially in their business.

A separate ledger account should be provided for each class of stock sold which account is debited at the end of each month with the total subscriptions received and credited through the cash book with collections during the month. The detail records showing the amounts due from the various purchasers can then be kept in a separate ledger, cards, or whatever form of record may be found the most desirable.

Capital Stock

Separate accounts must be maintained in the general ledger for each class of stock issued. The detail of stock ownership is carried in subsidiary records.

Funded Debt

As in the case of capital stock, separate accounts must be kept in the general ledger for each class of funded debt issued.

Bonds are usually issued under a deed of trust. Where they are so issued the trustee keeps such records as are required to show the holders of registered bonds, etc. When the interest falls due the company issuing the bonds pays to the trustee an amount sufficient to cover the interest on all bonds outstanding. The trustee then pays the interest to the holders of the bonds upon presentation of the interest coupon, if coupon bonds have been issued, or in the case of registered bonds by mailing a check to the holder. When a trustee is so appointed the corporation itself is not required to keep any records showing the ownership of this class of securities.

Notes Payable

As in the case of notes receivable the detail required of notes payable cannot all be shown in the general ledger. A separate record is necessary to show the date of the note, to whom issued, amount, rates of interest and when payable.

Accounts Payable

The record of accounts payable is usually kept in a voucher register. As approved invoices are received a voucher is drawn for the amount and the number of voucher, name and amount, entered in the register. When the voucher is paid the date of payment is entered in the register. The total of vouchers issued is posted to the general ledger account at the end of each month from the register, and the total vouchers paid is posted from the cash book, a separate column being provided under cash disbursements for this purpose.

At the end of each month a list of the unpaid vouchers should be taken off the voucher register which must be reconciled with the balance shown in the general ledger.

Consumers' Deposits

If the policy of a utility is to require deposits as security for the payment of bills, a record must be kept of the amount received from each customer. The total of cash received is posted each month to the credit of the general ledger account and refunds debited. The detailed record should show the deposit number, name, address, and amount of deposit. As deposits are refunded the date refunded is entered against the individual deposit. The open items in the detailed record must correspond with the general ledger balance.

The detail record may be kept on cards or in book form, columns being provided to show the required information. The advantage of card records is that as deposits are refunded the cards can be removed to a dead file so that a list of the open items can be taken off more readily than if it were necessary to go over a record where the greater portion of the deposits may have been refunded.

Depreciation Reserves

Accounts should be provided in the general ledger for each class of operation in which the company is engaged. Subsidiary records should be kept to show the detail of charges made against the reserve.

Revenue Accounts

If a utility is engaged in only one class of operation, the detail required can readily be carried in the general ledger. If engaged in various operations and possibly in a number of districts where it is desired to keep separate the revenue derived from each district, a controlling account may be opened and the detail carried in a subsidiary record.

Operating Expense Accounts

The detail of operating expenses required of class "A" companies as provided by prescribed classifications is such that such companies should not attempt to keep this information in the general ledger. Accounts should, however, be provided for each class of operation in which the company is engaged.

If a voucher distribution register is kept, columns are provided to give the distribution required for the general ledger, and the total of the different columns provided in the register is posted at the end of each month. The detail of the operating expenses can then be carried in a separate record.

General

While some of our members have very decided views upon this subject, believing that general ledgers should be limited to balance sheet accounts only, the committee offers no specific recommendation, particularly in view of the fact that controls may impose keeping of auxiliary records not necessarily essential in the smaller company.

Commercial Section Reports

Executive Committee[2]

The Commercial Section is just completing its first year of operation under the new plan of organization adopted last year, in which the vice-chairmen of the section and the bureaus succeed to the chairmanship the following year. The organization set up for the year just closing is as follows:

Section chairman, J. C. Plankinton.
Section vice-chairman, Lewis A. Lewis.
Lighting bureau chairman, F. H. Murphy. Vice-chairman, Fred Zaugg.

Committees: Home and industrial lighting, Fred Zaugg, chairman. Street and highway lighting, W. M. Hamilton, chairman. Electric advertising, committee not completed.

Power bureau chairman, George C. Sawyer. Vice-chairman, E. E. Scofield.

Committees: Commercial cooking, R. W. Faville, chairman. Competitive power, W. H. McMurray, chairman. Industrial heating, J. D. Scott, chairman. Rural electric service, J. C. Scott, chairman.

Merchandising bureau chairman, J. L. White. Vice-chairman, V. H. Moon.

Committees: General merchandising, V. H. Moon, chairman. Domestic electric range, R. B. McElroy, chairman. Domestic electric refrigeration, H. M. Ferguson, chairman.

The executive committee of the section believes that this form of organization lends itself to efficient work in the section and should be continued. It is known at the present time who will be responsible for the section's activities during the coming year, and the section is, therefore, in a position to complete its organization at once and proceed with its program for 1928-1929.

The executive committee has held three meetings during the past year. Also it conducted the third annual Midwinter Conference of the section, Feb. 20 and 21, 1928, in Portland. It is the opinion of the committee that these midwinter conferences are a very important part of the activities of the section, and should be continued annually.

[2] **J. C. Plankinton,** Northwestern Electric Company, chairman. **Lewis A. Lewis,** The Washington Water Power Company, vice-chairman. **F. H. Murphy,** Portland Electric Power Company, chairman, Lighting Bureau. **Fred Zaugg,** Northwestern Electric Company, vice-chairman, Lighting Bureau. **Geo. C. Sawyer,** Pacific Power & Light Company, chairman, Power Bureau. **E. E. Scofield,** The Washington Water Power Company, vice-chairman, Power Bureau. **J. L. White,** Portland Electric Power Company, chairman, Merchandising Bureau. **V. H. Moon,** Pacific Power & Light Company, vice-chairman, Merchandising Bureau.

Lighting Bureau

Home and Industrial Lighting*

The selling of proper indoor lighting is a different problem from that of selling any other thing that an electric utility company offers to the public. We don't have to sell the idea of using light for the first time, as we do with a range, a heater, or any other of the current-consuming devices, because everybody uses some light and gets some kind of a result. The problem is to get them to use the right amount and the right kind of a light, that which we know to be the best for their particular condition and location.

There have been many improvements and refinements made in lamps and lighting equipment in the last three or four years, and also much scientific research work has been done and data compiled to tell us all of the various things that must be taken into consideration in making up the correct lighting job. It used to be the practice to put any size or kind of lamp here, there or any place and let it go at that, but now we carefully consider all the local conditions in each case and install the right size and kind of luminaire in the right location to produce the best and most efficient illumination. This gives satisfaction to our customers and a profit to the industry. A customer with a well lighted home is a satisfied one, he is willing to pay for more and better lighting when we show him how he benefits by it.

In our desire to build load faster than normal growth, the development of the use of light offers one of the richest fields. Fully 80 per cent of the commercial and industrial establishments in the Northwest are operating under inadequate and poor lighting. Lighting men are now recommending and installing lighting intensities ranging from 12 to 25 foot-candles in stores, offices and manufacturing plants, and can show that it is economically good business for the owners to put in such installations. We should not overlook the fact that only about 20 per cent of our total kw.-hr. output goes for lighting, but it produces about 50 per cent of our total revnue.

Educational Program Undertaken

The committee believes that the successful selling of proper lighting requires a very large educational and promotional effort. It, therefore, undertook to handle a program of this nature, prepared by Clark Baker, National Lamp Works, Oakland, Calif. This program consists of a thirty-minute talk addressed to business men entitled, "The Story of Artificial Light, Its Accomplishments and Achievements." The talk is interwoven with several unusual lighting demonstrations that are very convincing and effective in an educational way. It is designed to tell of and show actual lighting effects as they apply to the home commerce, industry, schools and streets, with the idea of arousing an interest on the part of those who might have some influence on the installation of lighting both private and public in the community, thereby helping to break down sales resistance. A copy of this story is appended.

The committee set out to present the story to 29 business men's luncheon clubs, Lions, Kiwanis, Ad, Commercial, etc., in the following cities of the Northwest division: Seattle, Portland, Spokane, Salt Lake, Boise, Walla Walla, Yakima, Everett, Salem and Albany. It was estimated that the message could be placed before

* **Fred Zaugg,** Northwestern Electric Company, chairman. **Club Contact and Speakers Committees—Portland:** A. M. McMillan, Graybar Electric Company; George Sullivan, Portland Electric Power Company; Walter Potter, National Lamp Works. **Seattle:** R. M. Boykin and L. E. Karrer, Puget Sound Power & Light Company; J. H. Kelly, Graybar Electric Company. **Spokane:** J. E. E. Royer and L. K. Snyder, The Washington Water Power Company. **Boise:** L. W. Brainard and George Kincaid, Idaho Power Company. **Salt Lake City:** R. M. Bleak and K. W. Browning, Utah Power & Light Company. **Yakima:** B. P. Bailey, Pacific Power & Light Company. **Walla Walla:** R. B. Bragg, Pacific Power & Light Company. **Salem:** W. M. Hamilton, Portland Electric Power Company. **Albany:** G. L. Jackson, Mountain States Power Company. **Everett:** George Newell, Pudget Sound Power & Light Company.

two thousand representative men in this way, and that considerable newspaper mention would result.

On July 15, 1927, the committee chairman started to construct five complete sets of demonstration equipment, each set consisting of the main lighting box, 32 x 38 x 13 in., with 14 lamps in it, a ten-switch control box, four hand-painted background cards, five lettered and diagrammatic charts, three pieces of miniature furniture and several other small accessories. These sets were distributed to Salt Lake, Spokane and Seattle, with two kept in Portland where speakers were provided for the smaller cities of Washington and Oregon. One set was always on hand for a speaker to make any scheduled talk in the near-by cities.

Speakers Trained

On Aug. 15, 1927, the committee chairman met Mr. Baker in Salt Lake City, where a local committee was organized to arrange for speaking dates with the clubs and to present the talk. The equipment was set up and Mr. Baker coached and rehearsed the speaker on the talk and demonstrations until it was felt that he could put it on in a satisfactory and creditable manner. Jobbers, manufacturers' representatives, and others in the industry who are directly interested in lighting were advised of the program so that they might take advantage of what it offered them in a commercial way. Four days were required to complete the work in Salt Lake.

One day was then spent in Boise organizing a local committee and coaching the speaker. The speaker here having attended Mr. Baker's lighting school of last year, was familiar with the equipment. The Spokane set was sent to Boise for the scheduled presentations. The local contractors and others directly interested were informed of the program. From Boise the schedule of the chairman and Mr. Baker took them to Spokane, Seattle and Portland, where the process of training speakers and informing the lighting men of the industry about the program was continued. Three days were spent in each city on this work, and it was then felt that the program could go forward.

Summary of Talks and Results

Table I gives a detailed schedule of the speaking program.

In summing up the accomplishments of the committee we find that 31 appearances have been made before various clubs and that 2,712 business men have heard the talk at these meetings. There are on hand 97 in. of newspaper publicity, which does not include some additional mention of which the committee secured no copy.

It will be noted that the talk was presented before several more clubs than had been planned. There was a demand on the part of the clubs for the story, and it was necessary to refuse several requests because of inability to handle them. It was felt by the committee that at a later date the member companies could arrange for the presentation of the talk on their own properties, which would be of benefit to them and fill the demand.

The talk was presented over the radio in Salt Lake City, Portland and Seattle, and thus reached a very large audience in which benefit to the industry will be reflected.

There has been much favorable comment from business men in all parts of the Northwest as a result of the presentation of the "Story of Artificial Light," and a number of letters from different central station men have testified to the success of the program. There can be no doubt that even though the talk contains nothing of a commercial nature, it still has a large promotional value which can be turned to advantage not only by the central stations but by the equipment companies as well. It has given business men a greater appreciation of the fundamentals of good lighting and will make it easier to sell good lighting installations to them.

Salt Lake School

An insistent demand for a lighting school in Salt Lake, like those held last year in Seattle, Portland and Spokane, lead to the conduct of such a school there Jan. 16 to 19, 1928. Mr. Baker consented to give his time for the purpose of directing it. There were 19 electrical contractor representatives, 15 jobber salesmen and nine central station men registered. Also at each meeting there were several additional, or non-registered people in attendance. The response in attendance and general enthusiasm shown by the students fully justified its presentation.

Suggested Program for Next Year

A program of an educational nature to be presented before women's clubs and parent-teachers' groups on better lighting in the homes and schools, has been outlined by Mr. Baker and the committee recommends that this be carried through during the coming year. It is undoubtedly a step in the right direction in the promotion of more and better light.

"Story of Artificial Light"

There is a group of men who deal with the fastest known element in existence—light—the speed of which is 186,000 miles per sec. It takes 8 min. and 20 sec. for the light of the sun to reach the earth, the sun being 93 million miles away.

TABLE I—Speaking Program.

City	Clubs	Speaker	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Attendance
Seattle	Kiwanis	Kelly	1						200
	Lions	Kelly	28						100
	Gyro	Karrer				8			40
	Electric Club	Karrer			9				80
	Young Men's Business	Karrer		8					200
	Knights of Round Table	Karrer		7					60
	Exchange Club	Kelly				29			50
	Pur. Agents' Assn	Kelly			12				75
Salt Lake	Lions	Browning		16					50
	Kiwanis	Browning		29					115
	Exchange Club	Browning			13				105
Ogden	Kiwanis-Lions	Browning			23				80
Portland	Kiwanis	Zaugg					6		120
	City Club	Zaugg		9					135
	Ad Club							x	est 50
	Lions							x	est 60
	East Side Commercial	Zaugg						19	est 150
	Contractor-dealers	Zaugg				13			30
Salem	Chamber of Commerce	McMillan			16				110
	Rotary	Zaugg	2						90
Yakima	Rotary	McMillan	10						85
	Kiwanis	McMillan	15						80
Boise	Rotary							x	est 80
	Kiwanis	Potter					13		92
Walla Walla	Kiwanis	McMillan	16						75
	Rotary	McMillan	17						75
Vancouver	Kiwanis	Zaugg						12	85
	Rotary	Zaugg						27	est 75
Albany	Chamber of Commerce	McMillan	30						90
Spokane	Women's Comm. N.E.L.A.	Snyder		12					
Everett	Foremen's	Kelly					7		75
					Total Attendance				2,712

We marvel at the courage and daring of men who in airplanes have succeeded in attaining a speed of 300 miles per hour. If this could be kept up—and some day it undoubtedly will—it would take 18,600,000 min. to cover the distance between the earth and the sun; 18,600,000 min. is 310,000 hours or 36 years.

Compare 36 years with 8 min. Yet the group of men who are dealing with the 8 min. element are hardly known.

Lighting experts can send a beam of light twelve miles into the air instantly. The greatest altitude reached so far by airplane has been approximately seven miles, and that has only been accomplished once.

We occasionally read a front page headline something like this in effect: "DARING AVIATORS PLAN NIGHT FLYING," then in smaller type (indicating secondary importance) "with the aid of powerful searchlights as beacons." And that's the point. "Powerful Searchlights"—quicker than the flash of an eye, beams of light, thousands of candlepower are sent **miles** into the air, and **controlled, absolutely controlled**, which makes the art and science of artificial light most attractive and interesting, especially to its makers.

It is of light control, or controlled light, we want to talk today.

Compare for a moment the mighty beams of searchlights used as beacons at sea for the protection of human lives, to this tiny light (show grain of wheat lamp lighted) which is used in a doctor's instrument, the application of which is clearly illustrated in the following story.

A few years ago a little boy in Chicago somehow got a peanut lodged in his throat in such a way that unless it could be removed, he would slowly choke to death. The child's father sent for the doctor at once, and for an hour and a half the physician worked over the lad's tiny throat. If he could not get the stubborn little particle out, the child would die. If in his efforts, he pushed it ever so little in the wrong direction, he would choke at once. If at one instant the doctor's hand had faltered, or struck wrong, the child's fight would have been lost. And afterward, when the boy's father gave the doctor a beautiful cigarette case, it wasn't with any sense of marking his gratitude, it was just a little reminder of something that he hoped the physician would never forget,

The doctor's skill saved the child's life. But not the doctor's skill alone. There was something else, without which all the skill in the world would have been helpless. There was one little thing, something hardly anyone would have noticed at all, except as a "matter of course," without which no power on earth could have saved the boy. In the darkness of the little throat the doctor must have light . . . (flash the instrument) . . . He could see. The little boy's life really depended upon and was saved by electric light.

And so on through the whole range of artificial light-making, giving us pride in our achievements; giving us also the right to be proud of the advance in the art and science of illumination, which has brought **safety in the streets—efficiency in industry and commerce—elimination of eye strain and fatigue in class study**—and last but not least, has brought **comfort, cheerfulness and happiness into the home.**

And yet, do we enjoy all of these things? I don't believe we do; not because they are not there, but because we perhaps haven't as yet fully realized the completeness and fullness with which we could enjoy all of them if the application of artificial light were properly employed.

In order that we may know why light should be properly employed, it is necessary for us to understand something about that part of our body which functions with light, the eye. Light and sight are so closely related that without one the other would be useless.

It may safely be said the eye is the most marvelous piece of machinery in the human body. Likewise, the eye is the most flexible and abuse-resisting organ we possess.

In main structural characteristics it is like a camera; though a camera is more or less an arbitrary medium, whereas the eye is flexible. (Show Chart No. 1.)

Remarks for Chart No. 1—Let us examine this chart which shows the relation of light to sight. A rough sketch of the eye—the stationary lens—the iris—the focusing lens—the retina. Light enters the eye through the stationary lens, the iris opens or closes automatically controlling the amount of light that should be received, then passes through the focusing lens, focusing an image on the retina.

In considering proper or improper lighting in relation to the eye, there are two main abuses—gloom and glare: Gloom caused by **too little light**; and glare, by **too much light reaching the eye from an improper direction or misplaced light source.**

First then, let us consider the effect of gloom on the eye. The human eye **chemically** is adaptable to such a degree that it can differentiate between relative degrees of light, and **mechanically** adaptable to such a degree as to differentiate form. Therefore, the recognition of detail needs varying degrees of light or illumination upon the form object.

For instance, this chart (Chart No. 2.) we will assume to have an object at this point, say 14 inches from the eye, which is normal reading distance. Following the lines from the object through the lens of the eye, we find the image this size on the retina of the eye.

Assuming now there is not sufficient light on this object to be seen clearly at this distance, the only other thing to do then, is to draw the object closer to the eye, which enlarges the image on the retina.

But in doing this, we do two things, one dangerous, the other unnatural. The dangerous thing is—accident hazard; the nearer a worker's eyes are to moving objects, the greater the danger of accidents to them. Likewise, in the case of fast-moving machinery, there is the danger of clothes getting caught, etc.

The unnatural thing is, whenever we bring an object close to our eyes, we have to turn the eyes inward as shown here. With the object out at this point, the line goes through the center of the focusing lens to the retina. It may clearly be seen as the object is drawn closer how the lens would have to turn inward so as to focus properly, and this demands muscular effort on the part of little delicate eye muscles. These eye muscles are not made for prolonged exertion, but are made for fine and quick adjustments. This prolonged turning-in taxes the nervous system, and produces one of the most common forms of eye strain.

Further, every inch closer to our face we bring an object, shortens our focus. This also is an act that nature never meant us to maintain for long periods of time. The mechanism of this act uses one of the most delicate muscular parts of the entire body, and the drain upon nerve energy from this source produces not merely eye strain, but extreme general bodily fatigue.

We will now turn to the equal and much more common lighting fault, "glare." This, you will remember, we spoke of as too much light reaching the eye from an improper direction, or misplaced light source, and inasmuch as we demonstrate glare and its effect a little later, we will pass it for the moment and describe it at the time of its demonstration.

We spoke of safety in the streets. Surveys conducted in the larger cities where they have what is commly called "White Ways" or "Paths of Gold," together with other well-lighted streets, show a 78 per cent decrease in crime, likewise a 31 decrease in street accidents.

These results are directly traceable to the scientific study of illumination in the streets by lighting experts and specialists. A totally different study is required in the down-town section of a city from that of a semi-business district, while the outlying and residence sections require still another application.

From the street we enter the school-room. This phase of lighting has had a more extensive study by lighting experts than many other phases of lighting, because it first of all affects our younger generation Likewise, by reason of more experience and experiments in this field, more data have been compiled.

Recent extensive surveys have shown that at least 25 per cent of our school children have defective eyesight. In the lower grades the percentage is less than this, but there are marked increases in the number and extent of eye defects as the children progress through the school-life.

Let us look at this chart for a moment:

24,000,000—school enrollment
25 per cent
6,000,000—defective vision

67 per cent
4,020,000—retarded in study
$64.15—cost per pupil per year

$257,800,000—ineffectively used because of
(turn to another chart)

Poor control of natural light;
Incorrect artificial light;
Glare from highly polished surfaces;
Home-reading in poor light, or none at all;
Distance at which work is held;
Poorly lighted blackboards;
Blackboards wrongly placed in respect to windows;
Too much contrast in room;

Lack of education in the use of light with respect to the eye.

Time will not permit taking up each of these items. However, they have been and are agreed upon, not only by illumination engineers, but those in authority on optometry, and also by physicians who specialize on the eye, together with the executives of our educational institutions, as being those things that are largely responsible for this 25 per cent of children having defective vision. Likewise these same authorities agree that correction of the items mentioned will remedy this condtiion.

The growing use of schools for night courses makes it doubly important that lighting specialists give their best to research and study in this field of lighting, since the night classes are of necessity entirely dependent on artificial illumination.

As a result of the work of illuminating engineers and specialists, a code of lighting school buildings has been prepared by a committee consisting of 20 organizations and societies identified with school-lighting problems in one or another of its various aspects. The American Engineering Standards Committee has approved this code as the American standard. It now serves as a guide for the enactment of legislation on school-lighting, and likewise provides architects with detailed information on which to base proper school lighting specifications. This is an achievement of which makers of artificial light are proud.

As we approach industry, the factory or manufacturing plant is our first contact. In this field, lighting engineers and lighting specialists have many accomplishments and achievements marked up to their credit. However, here we must effect economic efficiency. We have been able actually to increase production by reason of good illumination, likewise, have decreased spoilage to a very large extent by reason of good illumination, together with largely eliminating accident hazards. This latter is of prime importance and has had much of the lighting engineer's time.

Insurance and accident commission statistics show that 18 per cent of all industrial accidents are due to poor or inadequate illumination.

We will demonstrate one or two lighting principle which are effective in the factory.

First, shadows—(demonstrate). It can be seen from this if sharp shadows are permitted, the object itself will be confused with its shadows. The opposite to this is the absence of shadows —(demonstrate total diffiusion). It can be seen that without shadow we cannot observe objects in their three dimensions. (switch lights on from one side). You now see these objects in their true form (then switch back to total diffusion), now their form is not recognized (turn out light). There is happy medium between sharp shadows and the entire elimination of them, which speeds labor and prevents accidents.

The next is a demonstration of the greatest evil in lighting practice—glare. It not only reduces one's ability to see detail clearly and quickly, but has been known to effect temporary blindness. (Put in glare card—have it ready—then put light back of hole in card. Call attention to inability to read close to the hole.) Now it is difficult to read even some of the large lettering.

A study of these things we have just demonstrated, namely, shadows, glare and light diffusion, does not confine itself to factory work alone, but comes in for a major part of the engineer's attention, when we go into the factory executive's office or in offices generally.

We find in clerical work with too low an intensity of lighting, the eye is soon fatigued, while glaring light sources or glaring reflection surfaces, such as glass-topped desks, glossy or shiny paper, seriously impair the efficiency of employees. With dancing or shifting shadows on typewriter keys, eye strain is introduced. These effects are particularly serious in clerical and stenographic offices where a high percentage of women are employed, where a study shows that women by nature, are more sensitive to such effects than men.

Lighting engineers, time upon time, have increased efficiency in office work and reduced the number of absentees by properly installed high intensity lighting in offices.

There are many other elements entering into office lighting, such as kinds of paper used, objects of brightness, placing of desks for natural light vs. artificial light, desk lamps, etc. Time here does not permit a discussion of these, and it is to be regretted, for their importance goes hand in hand not only with the efficiency, but with the comfort and health of the office employee.

In a store also the question of employees' comfort and health has been effectively dealt with. Store merchandisers have warmly received and highly praised makers of artificial light for their contribution to better merchandisinb by reason of better lighting.

Unselfish and non-commercial study has been made by specialists in this field, all of which now, however, have a commercial value to all concerned. This is the natural outcome of research work done. Modern merchants, satisfying themselves of the value of the right kind of light, now demand it as an integral part of modern merchandising.

The term, "right kind of light," covers a great many points, all of equal importance. A discussion of each would perhaps be interesting. We will confine ourselves, however, on account of time, to a demonstration of one principle largely involved—that is—light absorption.

This demonstration will show why one section of a store will have a different appearance from that of another section, when the lighting units used are the same in each case.

(High switch—white card. You are now in the white goods, or linen department of a store. I will transport you now to the dress goods department (pull out white card). I will now take you back to the linen department (pull out dark card). This difference in appearance is due to absorption of light falling on the merchandise. The light-colored fabrics here shown are absorbing approximately 20 per cent of the light falling upon them, while the darker goods we just looked at absorbed approximately 80 per cent of the light. I will now transport you to another department—draperies perhaps—at least, veri-colored fabrics. Here we are absorbing approximately 30 or 40 per cent of the light.

These conditions, once understood, were easily corrected, and many other things, presumably as simple, have brought about a greater understanding and appreciation of light principles and fundamentals as applied to the merchant.

Another important appreciation the merchant today has of light, is the psychological effect it has upon a purchaser, who may shop more readily and more comfortably under good illumination than poor illumination, and as before mentioned, the employees, i.e., the sales people, are more cheerful and their health is better when they work under the right kind and right amount of light.

Merchants likewise have responded to engineering and research data as to the value of good lighting in show windows. They know that light has a definite attracting or pulling power to their show windows. They know a window with this (high intensity with a display) amount of light attracts more people to it than this (switch low intensity) by as much as 70 per cent.

This percentage figure is variable, but is a recognized average. Many merchants, especially the large ones, place a dollar and cent value on their windows. The added percentage of pulling power by light is in direct proportion to the dollar and cent value; that is, a window with a value of $100. per hour, under this (switch low) amount of light, when changed to this (switch on high), which has an added pulling power of 70 per cent, now has a value of $170. per hour.

Color lighting is now being recognized as having an added value when properly used for displaying merchandise in show windows. A demonstration of color effects may be of interest.

This is the effect of colored light on colored fabric: (Switch from white to colored lights and back to white and repeat. No talking during changes).

A knowledge of pigment colors and light colors permits us to use both of them to the greatest advantage in the show-window, even to the background.

Color also comes in for its share of consideration in the home. Here there is no limit to how far a skilled designer may go in producing pleasing and unusual effects by the control of high lights, shade, and color.

We find, however, there are as many different ideas on design, color harmony, etc., in the home as there are individuals who control the home. One consideration which should always be given the home is that the illumination should be soft and free from glare. All lamp bulbs should be shaded. From there on, personal tastes may be the guide.

Occasionally, however, we find decorations and furnishings which have been selected for their rarity, or possibly their beauty, distorted by artificial light. The beauty of such furnishings and decorations is only enjoyed during daylight hours. It should be equally enjoyed under artificial light, and can be if some consideration is given the lighting condition surrounding them, for artificial lighting may be used as a decorative medium, or merely as an ornament.

Let us show one or two lighting effects in the home. Here is a floor lamp typical of those in many homes of today. (Floor lamp with red shade and red globes.)

Let us assume for a moment this lamp in a room where because of its beauty this floor covering has been selected, likewise, for its harmony with the color of the rug, together with its comfort, we will assume these furnishings; again assume this wall covering.

We cannot very well place this large floor lamp in this small display. However, we will transport the color, (turn out floor lamp and light red in display), the mulberry rug is now a red rug. The blue furniture pieces are black, and the wall is bathed in red. The original design of the room has been destroyed.

This need not be; for instance, (turn out the red light and put on the ivory). This does not mean, however, that the floor lamp cannot be used. It may be—like this, for instance (set in miniature floor-lamp). It now serves as an ornament and a reading lamp, but does not destroy our room design.

I hope these demonstrations have given each of you something. For me, I am one of the workers of artificial light, the light that man controls, the torch of civilization's march onward.

Street and Highway Lighting*

After reviewing the mass of data and information that has been compiled and published in recent years by those interested in street and highway lighting, one is reminded of the old saying, "There is nothing new under the sun." Time and again we read or hear of what at first seems to be a new idea regarding street lighting, only to find that it is simply an old idea that we have had for a long while, dressed up in new or different language or pictures.

Individuals, committees and organizations are inclined at times to compile and deliver to assemblages of their colleagues ponderous, long-winded reports, evidently either for the purpose of making a showing on an assignment, or an impression on a defenseless audience that the author has made a revolutionary discovery and is graciously presenting it, and the benefits to be derived therefrom, to said audience.

In this day and age of high pressure, intensive business and social life, most of us have time only to hit the high spots, and in our quest for knowledge, desire and seek condensed data and information on the specific subject in which we are for the moment most interested. With the foregoing thoughts in mind, this committee has tried to give some data in condensed form and has furnished references to other data and reports that may be of interest.

This is the second installment of a three-year serial report on a program suggested by the national committee and extended by last year's local committee over a three-year period.

The first, or last year's installment of the report, showed that the character of street lighting load is desirable; that the return per kw.-year is satisfactory; that the investment per kw. of load is reasonable; that the advertising is valuable; and that the field for development is large.

It is, therefore, desirable that we proceed to develop and expand this class of business.

How Much Are Cities Spending?

Since the greatest obstacle to the expansion of street and highway lighting is the lack of municipal or other governmental funds available to pay the cost of such lighting, your committee submits herewith data that we hope will be of help in persuading city and other officials to provide more adequate funds for this purpose. They generally desire to do so, but must be able satisfactorily to justify their action in the minds of their constituents.

The data given in Table I is of course not an **exact** measuring stick to determine the adequacy of street lighting expenditures because the factors of population per square mile, and rates for service also must be considered in determining **accurately** the adequacy of present or proposed lighting systems.

The similar data in Table II is from the Proceedings of the 1923 convention of the Pacific Coast Electrical Association, pages 81 to 84, wherein the data are given in detail for each town and city reported on in the territory of the association.

Data in Table III are from the transactions of the Illuminating Engineering Society, Vol. XX, No. 1, January, 1925, pages 22 to 26, wherein a greal deal of data of all kinds relative to street lighting are given in detail for 362 cities in the United States.

How Much Should a City Spend?

The question, "How much should a city spend annually, per capita, for street lighting?" cannot be answered accurately in any definite amount nor by the application of any formula, as far as the committee is informed.

Preston S. Millar, of the Electrical Testing Laboratories, has expressed the opinion that $1.75 per capita would be a reasonable amount.

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* **W. M. Hamilton,** Portland Electric Power Company, chairman. **The California Oregon Power Company:** J. C. Thompson. **Mountain States Power Company:** G. McClellan. **Northwestern Electric Company:** Fred Zaugg. **Pacific Power & Light Company:** Will T. Neill. **Puget Sound Power & Light Company:** W. A. Schoel.

TABLE I—Data relative to Street Lighting in Cities having a population of 1,000 and over in the territory of the Northwest Electric Light & Power Association.

(Accuracy of data not guaranteed)

City	Population	Company Serving	Yearly Street Ltg. Expenditures	Yearly Per Capita Expenditures	Per Cent Police Dept. Expense	Per Cent Total City Expense
(Cities of 1,000 to 3,000 Population)						
Snoqualmie, Wash.	2,000	P. S. P. & L. Co.	$ 480	0.24	53.0	10.4
Enumclaw, Wash.	2,000	P. S. P. & L. Co.	1,520	0.75	57.0	11.0
Port Orchard, Wash.	1,500	P. S. P. & L. Co.	631	0.42	42.1	13.3
Waterville, Wash.	1,200	P. S. P. & L. Co.	No record			
Leavenworth, Wash.	1,800	P. S. P. & L. Co.	2,982	1.66	66.3	27.1
Cashmere, Wash.	2,000	P. S. P. & L. Co.	553	0.28	14.2	5.2
Burlington, Wash.	1,700	P. S. P. & L. Co.	1,180	0.70	90.5	11.3
Winlock, Wash.	1,100	P. S. P. & L. Co.	894	0.81	82.0	11.0
Stanwood, Wash.	2,250	P. S. P. & L. Co.	1,700	0.75	100.0	20.0
Sumner, Wash.	2,300	P. S. P. & L. Co.	1,807	0.78	76.0	5.9
Elma, Wash.	1,650	P. S. P. & L. Co.	1,626	1.00	46.3	11.0
Goldendale, Wash.	1,500	P. P. & L. Co.	1,293	0.86	60.0	8.9
Clarkston, Wash.	2,200	P. P. & L. Co.	1,800	0.82	100.0	14.5
Pomeroy, Wash.	1,750	P. P. & L. Co.	1,503	0.85	62.6	7.2
Dayton, Wash.	2,700	P. P. & L. Co.	2,659	0.98	105.1	10.3
Waitsburg, Wash.	1,200	P. P. & L. Co.	1,667	1.39	131.5	13.5
Prosser, Wash.	1,700	P. P. & L. Co.	1,509	0.88	91.4	18.0
Wapato, Wash.	1,200	P. P. & L. Co.	1,228	1.02	45.5	11.8
Sunnyside, Wash.	2,200	P. P. & L. Co.	1,850	0.84	53.4	8.6
Grandview, Wash.	1,800	P. P. & L. Co.	1,000	0.55	50.0	8.0
Pullman, Wash.	2,800	W. W. P. Co.	4,060	1.45	151.5	4.0
Palouse, Wash.	1,800	W. W. P. Co.	2,052	1.14	145.3	19.4
Ritzville, Wash.	2,250	W. W. P. Co.	2,430	1.08	162.0	9.7
Okanogan, Wash.	1,500	W. W. P. Co.	1,551	1.03	575.0	9.1
Omak, Wash.	2,000	W. W. P. Co.	1,176	0.59	58.8	8.0
Odessa, Wash.	1,100	W. W. P. Co.	972	0.89	73.5	23.8
Tekoa, Wash.	1,800	W. W. P. Co.	2,079	1.15	74.1	15.3
Davenport, Wash.	1,200	W. W. P. Co.	1,917	1.60	1,115.0	16.8
Deer Park Wash.	1,300	Mt. Spokane P. Co.	931	0.71	46.1	No record
Ilwaco, Wash.	1,000	P. W. C. H. E. Co.	756	0.75	50.0	23.0
Colville, Wash.	2,000	S. C. P. & L. Co.	3,254	1.62	238.0	18.3
Beaverton, Ore.	1,200	P. E. P. Co.	1,604	1.33	213.8	68.2
Milwaukie, Ore.	2,000	P. E. P. Co.	2,441	1.22	230.5	20.1
West Linn, Ore.	1,500	P. E. P. Co.	3,000	2.00	833.3	7.0
Molalla, Ore.	1,000	P. E. P. Co.	200	0.20	18.1	1.6
Gladstone, Ore.	1,500	P. E. P. Co.	Free			
Woodburn, Ore.	1,850	P. E. P. Co.	2,059	1.11	163.5	16.2
Silverton, Ore.	3,000	P. E. P. Co.	2,507	0.83	156.3	7.7
Gresham, Ore.	1,500	P. E. P. Co.	1,430	0.95	No record	55.0
Joseph, Ore.	1,000	E. E. Co.	1,200	1.20	100.0	21.4
Enterprise, Ore.	2,000	E. E. Co.	1,800	0.90	100.3	16.0
Wallowa, Ore.	1,200	E. E. Co.	1,100	0.92	73.3	16.6
Freewater, Ore.	1,000	P. P. & L. Co.	345	0.34	16.4	5.2
Seaside (Winter), Ore.	3,000	P. P. & L. Co.	3,836	1.28	70.9	17.4
Condon, Ore.	1,200	P. P. & L. Co.	1,153	0.96	50.0	11.0
Heppner, Ore.	1,325	P. P. & L. Co.	1,686	1.27	130.0	9.3
Monmouth, Ore.	2,000	M. S. P. Co.	1,872	0.93	260.0	45.0
Independence, Ore.	1,800	M. S. P. Co.	1,947	1.08	103.7	13.0
Falls City, Ore.	1,200	M. S. P. Co.	1,210	1.00	190.0	25.0
Cottage Grove, Ore.	2,750	M. S. P. Co.	2,790	1.00	80.1	8.3
Coquille, Ore.	2,500	M. S. P. Co.	2,668	1.08	88.9	11.5
Myrtle Point, Ore.	1,700	M. S. P. Co.	1,218	0.71	147.7	21.0
Powers, Ore.	1,000	M. S. P. Co.	490	0.49	49.0	18.8
Lebanon, Ore.	2,500	M. S. P. Co.	2,400	0.96	86.6	16.6
Clatskanie, Ore.	1,500	P. W. C. H. E. Co.	845	0.56	47.0	16.9
Burns, Ore.	1,600	P. W. C. H. E. Co.	1,288	0.80	86.0	14.3
Elgin, Ore.	1,000	E. O. L. & P. Co.	750	0.75	93.7	9.3
Union, Ore.	1,400	E. O. L. & P. Co.	1,200	0.85	92.3	5.3
Redmond, Ore.	1,900	D. P. & L. Co.	1,123	0.59	62.4	7.9
Prineville, Ore.	1,100	D. P. & L. Co.	1,722	1.56	105.8	4.4
Ontario, Ore.	2,039	I. P. Co.	3,459	1.70	176.5	9.1
American Falls, Idaho	1,547	I. P. Co.	2,000	1.22	66.9	11.8
Buhl, Idaho	2,700	I. P. Co.	6,673	2.47	198.1	20.1
Emmett, Idaho	2,750	I. P. Co.	2,800	1.01	105.6	13.9
Filer, Idaho	1,071	I. P. Co.	1,359	1.22	225.9	9.9
Glenns Ferry, Idaho	1,350	I. P. Co.	1,841	1.36	61.4	8.5
Gooding, Idaho	1,950	I. P. Co.	2,178	1.11	150.0	9.3
Jerome, Idaho	2,100	I. P. Co.	4,018	1.91	287.1	11.3
Meridian, Idaho	1,002	I. P. Co.	1,537	1.53	91.3	25.4
Mountain Home, Idaho	1,700	I. P. Co.	3,507	2.06	251.5	176.9
Oakley, Idaho	1,000	I. P. Co.	1,253	1.25	104.2	43.4
Payette, Idaho	2,500	I. P. Co.	6,076	2.43	434.5	24.3
Shoshone, Idaho	1,000	I. P. Co.	1,941	1.94	108.0	27.7
Grangeville, Idaho	1,500	G. E. L. & P. Co.	1,863	1.24	133.5	13.4
Orofino, Idaho	1,200	G. E. L. & P. Co.	840	0.70	44.2	5.6
Salmon, Idaho	1,600	S. R. P. & L. Co.	2,400	1.50	120.0	12.8
St. Maries, Idaho	3,000	W. W. P. Co.	2,768	0.92	55.3	8.5
Ashton, Idaho	1,220	U. P. & L. Co.	1,377	1.13	76.5	7.5
Rexburg, Idaho	3,000	U. P. & L. Co.	3,566	1.18	189.0	9.3
Rigby, Idaho	2,000	U. P. & L. Co.	1,987	0.99	136.2	10.9
Shelley, Idaho	1,600	U. P. & L. Co.	2,078	1.30	110.8	9.9
St. Anthony, Idaho	3,000	U. P. & L. Co.	3,200	1.06	112.2	8.2
Sugar, City, Idaho	1,000	U. P. & L. Co.	499	0.50	69.3	8.5
Montpelier, Idaho	2,984	U. P. & L. Co.	3,314	1.10	113.4	11.7
Paris, Idaho	1,333	U. P. & L. Co.	1,272	0.92	141.3	13.7
Delta, Utah	2,800	P. P. & L. Co.	270	0.10	No record	No record
Hinckley, Utah	1,000	P. P. & L. Co.	459	0.46	No record	No record
Elsinore, Utah	1,000	T. P. Co.	598	0.60	No record	No record
Fillmore, Utah	2,500	T. P. Co.	1,830	0.73	No record	No record
Gunnison, Utah	1,800	T. P. Co.	1,768	1.00	No record	No record
Marysvale, Utah	1,100	T. P. Co.	603	0.55	No record	No record
Milford, Utah	1,800	T. P. Co.	1,845	1.00	No record	No record
Panguitch, Utah	1,100	P. T. Co.	658	0.60	No record	No record
Salina, Utah	2,000	T. P. Co.	1,085	0.54	No record	No record
Grantsville, Utah	1,165	U. P. & L. Co.	1,264	1.09	175.5	No record

TABLE I—Data relative to Street Lighting in Cities having a population of 1,000 and over in the territory of the Northwest Electric Light & Power Association—Continued.

(Accuracy of data not guaranteed)

City	Population	Company Serving	Yearly Street Ltg. Expenditures	Yearly Per Capita Expenditures	Per Cent Police Dept. Expense	Per Cent Total City Expense
Garland, Utah	1,000	U. P. & L. Co.	$ 1,452	1.45	156.4	8.2
Lewiston, Utah	2,000	U. P. & L. Co.	828	0.41	59.1	4.1
Richmond, Utah	1,400	U. P. & L. Co.	975	0.70	97.5	7.8
Smithfield City, Utah	2,700	U. P. & L. Co.	1,822	0.67	70.0	7.0
Tremonton, Utah	1,000	U. P. & L. Co.	2,025	2.02	168.7	8.9
Farmington, Utah	1,500	U. P. & L. Co.	1,040	0.70	70.0	No record
Layton, Utah	1,800	U. P. & L. Co.	620	0.35	103.3	No record
North Ogden, Utah	1,050	U. P. & L. Co.	120	0.12	No record	No record
Coalville Grove, Utah	1,150	U. P. & L. Co.	1,839	1.60	156.0	6.8
Pleasant Grove, Utah	1,682	U. P. & L. Co.	1,692	1.00	72.9	No record
Vernal, Utah	1,400	U. P. & L. Co.	1,166	0.83	46.2	No record
Midvale, Utah	2,000	U. P. & L. Co.	1,973	0.98	No record	No record
Sandy, Utah	1,400	U. P. & L. Co.	1,580	1.13	No record	No record
Hamilton, Montana	2,000	M. P. S. Co.	2,040	1.02	84.7	17.7
Green River, Wyoming	2,800	U. P. & L. Co.	4,500	1.61	100.0	17.3
(Cities of 3,000 to 5,000 Population)						
Blackfoot, Idaho	4,000	I. P. Co.	5,642	1.41	111.0	6.2
Preston, Idaho	3,235	U. P. & L. Co.	2,664	0.81	116.5	No record
Moscow, Idaho	5,000	W. W. P. Co.	8,200	1.64	264.5	9.1
Dallas, Ore	3,500	M. S. P. Co.	4,843	1.38	339.8	26.2
North Bend, Ore	4,000	M. S. P. Co.	4,043	1.01	120.2	22.4
Tillamook, Ore	3,500	M. S. P. Co.	4,600	1.32	104.0	14.2
Ashland, Ore	4,899	Municipal	5,000	1.02	100.0	38.3
Hillsboro, Ore	4,000	P. E. P. Co.	3,044	0.76	93.6	48.2
Hood River, Ore	3,600	P. P. & L. Co.	4,154	1.15	57.2	8.8
Newberg, Ore	3,500	Y. E. Co.	2,440	0.69	74.5	6.4
Richfield, Utah	3,600	T. P. Co.	3,258	0.90	No record	No record
American Fork, Utah	3,300	U. P. & L. Co.	2,913	0.88	94.3	No record
Eureka, Utah	4,150	U. P. & L. Co.	3,744	0.90	60.7	No record
Park City, Utah	4,500	U. P. & L. Co.	4,890	1.09	53.8	11.3
Camas, Wash	3,500	N. W. E. Co.	1,500	0.43	43.0	4.4
Toppenish, Wash	3,600	P. P. & L.	3,520	0.98	51.1	11.3
Auburn, Wash	4,600	P. S. P. & L.	2,981	0.65	80.0	13.9
Kent, Wash	3,200	P. S. P. & L.	2,400	0.75	66.8	5.2
Kirkland, Wash	3,700	P. S. P. & L.	2,852	0.77	150.1	28.5
Montesano, Wash	3,500	P. S. P. & L.	1,812	0.52	90.0	14.4
Renton, Wash	4,800	P. S. P. & L.	2,116	0.44	32.6	4.2
Port Townsend, Wash	3,500	P. S. P. & L.	2,090	0.59	82.5	13.5
Sedro Wooley, Wash	3,500	P. S. P. & L.	2,236	0.64	80.0	12.8
Mt. Vernon, Wash	3,700	P. S. P. & L.	3,680	1.00	104.2	10.7
Shelton, Wash	3,600	P. W. C. H. E.	2,208	0.41	58.7	3.2
South Bend, Wash	4,000	P. W. C. H. E.	2,455	0.61	98.2	14.4
Colfax, Wash	3,300	W. W. P. Co.	4,068	1.23	139.1	12.4
Evanston, Wyoming	3,300	U. P. & L. Co.	5,149	1.56	129.0	No record
(Cities of 5,000 to 10,000 Population)						
Caldwell, Idaho	5,600	I. P. Co.	6,884	1.23	159.0	4.4
Coeur D'Alene, Idaho	10,000	K. P. Co.	7,027	0.70	118.6	No record
Lewiston, Idaho	9,500	P. P. & L. Co.	10,500	1.10	82.9	4.4
Grants Pass, Ore	6,000	C. O. P. Co.	5,400	0.90	87.6	12.3
Roseburg, Ore	7,972	C. O. P. Co.	6,400	0.82	128.0	15.6
Bend, Ore	9,500	D. P. & L. Co.	6,034	0.63	48.0	5.5
LaGrande, Ore	9,700	E. O. L. & P. Co.	11,500	1.18	109.5	8.5
Marshfield, Ore	6,000	M. S. P. Co.	6,982	1.16	108.4	16.6
Albany, Ore	6,000	M. S. P. Co.	6,400	1.06	124.8	16.5
Oregon City, Ore	7,000	P. E. P. Co.	5,400	0.77	61.1	5.7
Pendleton, Ore	7,000	P. P. & L. Co.	8,546	1.22	89.0	9.0
Seaside (Summer), Ore	10,000	P. P. & L. Co.	5,393	0.54	100.0	24.4
The Dalles, Ore	6,800	P. P. & L. Co.	5,317	0.78	63.8	9.5
Baker, Ore	9,000	City	9,600	1.06	95.0	7.5
Bingham, Utah	5,600	U. P. & L. Co.	3,240	0.60	36.0	No record
Tooele, Utah	5,750	U. P. & L. Co.	1,967	0.34	41.0	No record
Port Angeles, Wash	10,000	City	7,791	0.78	73.5	4.0
Chehalis, Wash	7,000	P. S. P. & L. Co.	3,666	0.52	43.5	8.7
Puyallup, Wash	7,700	P. S. P. & L. Co.	5,435	0.70	78.5	10.3
Longview, Wash	10,000	W. G. & E. Co.	2,941	0.29	No record	100.0
(Cities of 10,000 to 20,000 Population)						
Bremerton, Wash	13,000	P. S. P. & L. Co.	5,230	0.40	29.0	2.2
Wenatchee, Wash	10,500	P. S. P. & L. Co.	7,000	0.66	30.2	4.7
Kelso, Wash	10,300	P. S. P. & L. Co.	7,394	0.71	59.5	3.1
Walla Walla, Wash	17,000	P. P. L. Co.	19,492	1.14	79.4	8.1
Hoquiam, Wash	15,000	G. H. R. & L. Co.	8,310	0.55	37.7	6.3
Vancouver, Wash	17,650	N. W. E. Co. & P. E. P.	9,903	0.56	48.4	5.4
Astoria, Ore	15,000	P. P. L. Co.	18,719	1.22	90.5	14.2
Medford, Ore	12,200	C. O. P. Co.	7,200	0.59	75.3	8.3
Klamath Falls, Ore	15,000	C. O. P. Co.	6,365	0.42	25.1	5.0
Helena, Mont	12,000	H. G. & E. Co.	21,645	1.80	90.5	9.6
Missoula, Mont	16,000	M. P. S. Co.	19,975	1.24	100.1	14.8
Nampa, Idaho	11,160	I. P. Co.	9,680	0.86	103.1	7.0
Pocatello, Idaho	18,000	I. P. Co.	21,500	1.19	51.3	7.2
Provo, Utah	16,100	U. P. & L. Co.	15,906	0.93	142.6	5.3
(Cities of 20,000 and over in Population)						
Portland, Ore	337,700	P.E.P.Co.&N.W.E.Co.	372,322	1.10	40.3	6.2
Salem, Ore	25,000	P. E. P. Co.	19,134	0.76	61.5	6.9
Aberdeen, Wash	25,000	G. H. Ry. & L. Co.	17,800	0.71	87.6	8.0
Bellingham, Wash	35,500	P. S. P. & L. Co.	11,040	0.31	20.9	1.9
Everett, Wash	40,000	P. S. P. & L. Co.	12,434	0.31	23.5	4.8
Spokane, Wash	127,000	W. W. P. Co.	98,156	0.77	21.1	4.7
Yakima, Wash	26,600	P. P. & L. Co.	16,464	0.62	34.1	6.3
Boise, Idaho	23,042	I. P. Co.	24,487	1.06	57.9	8.9
Ogden, Utah	36,000	U. P. & L. Co.	36,569	1.01	50.2	No record
Salt Lake City, Utah	150,000	U. P. & L. Co.	125,762	0.80	No record	No record

The 1923 street lighting committee of the Pacific Coast Electrical Association, whose data are given made the following recommendation:

Population of Cities	Per Capita per Year
1,000 to 5,000	$2.00
5,000 to 20,000	1.75
20,000 and over	1.50

It is interesting to note that the 1926 committee of the same association makes the following recommendations for proper illumination of all streets, based on their observations of the experience of well lighted cities throughout the United States:

Population of Cities	Per Capita per Year
Less than 5,000	$2.50
5,000 to 20,000	2.00
20,000 to 100,000	1.75
Over 100,000	1.50

The progress and increase in the importance of street lighting in the three years between the two reports is reflected in the increase in the amounts listed for cities

TABLE II—Street Light Data from 1923 N.E.L.A. Proceedings.

Range of Population	Number of Towns and Cities	Total Population	Yearly Street Lighting Expenditure	Yearly Expenditure Per Capita
Less than 1,000	53	29,374	$ 52,752.50	$1.80
1,000 to 3,000	73	138,018	149,327.00	1.08
3,000 to 5,000	27	128,865	119,766.84	0.93
5,000 to 10,000	27	170,890	190,425.00	1.12
10,000 to 20,000	10	154,000	172,648.00	1.12
Over 20,000	15	2,007,352	1,860,306.00	0.93
EASTERN CITIES				
100,000 to 400,000	6	1,200,910	$1,413,171.00	$1.18

of 100,000 and less, ranging from 25 cents to 50 cents per capita.

The national street lighting committee says in its 1927 report, "It is generally conceded that in the average American city an annual expenditure per capita of not less than $2 is justified by its returns in decreased accidents, decreased crime, increased conveniences of urban life and increase in property values."

It is self-evident that the amount of money that different cities will spend, per capita, will depend very largely on local economic and social conditions rather than on engineering principles. An illustration of this

TABLE III—Street Light Data from I. E. S.

Range of Population	Average Population	Number of Cities in group	Annual Cost Per Capita	Annual Cost Per Mile
10,000 to 20,000	13,750	165	$1.02	$408
20,000 to 30,000	24,100	54	0.90	414
30,000 to 40,000	34,400	37	0.91	471
40,000 to 50,000	44,400	26	0.94	554
50,000 to 75,000	60,900	30	0.94	474
75,000 to 100,000	87,500	15	0.93	487
100,000 to 150,000	122,000	12	0.86	708
150,000 to 200,000	169,500	8	0.74	427
200,000 to 300,000	236,500	9	0.93	604
300,000 to 500,000	376,000	6	0.85	558

point is found in the 1923 P.C.E.A. reports wherein we find that the cites paying the most per capita, and also the least, are both found in the class of less than 1,000 population:

City	Population	Per Capita Expenditure
Beverly Hills	800	$18.70
Kennett	464	.14

The capitalists, movie stars and wealthy people generally who have their homes in Beverly Hills, can afford to pay a relatively large amount for, and want, high class street lighting. The miners and their associates in Kennett, being quite poor and wanting other things more than street lighting, naturally can and will only pay for a meager class of service.

These can be no refuting the fact that the great increase in speed and density of traffic upon our streets and highways during recent years, due to the introduction and adoption of motor vehicles and the construction of paved and macadamized road beds, has necessitated a corresponding increase in the illumination of such streets and highways that has not been forthcoming to date. On the other hand, we must recognize that there have been and are other demands upon public funds for similarly increasing requirements along other lines and we must be governed accordingly in our recommendations and efforts to sell street and highway lighting, if we would build and hold a reputation for well balanced judgment and honesty in such matters.

Cost of Auto Accidents

One of the best "dollar and cents" arguments for adequate street and highway lighting is "cost" of auto accidents due to poor lighting. Nearly every one has a car or drives one today and is fully alive to the potential danger that lurks on every poorly lighted street or highway. Therefore, an appeal for better lighting based on the cost of accidents, will reach attentive ears, or eyes.

Based on data obtained by the engineering department of the National Lamp Works from a study of traffic accidents in 32 cities, it was found that 17.6 per cent of all fatal night accidents were attributed to lack of light, and that of the billion dollar total annual loss estimated by Dr. F. S. Crum of the Prudential Insurance Company statistical department, $54,000,000 may be attributed to lack of light. U. S. Census reports show that the total expenditure for street lighting at the time of the last census in the United States was but $50,000,000. Therefore, if it could be assumed that by doubling the amount of street lighting this loss of $54,000,000 could be eliminated, the additional cost of that lighting would be more than justified to the extent of $4,000,000, to say nothing of the reduction in the loss of life.

Cost of Crime

Another "dollars and cents" argument for good street lighting is the saving effected by such lighting in the cost of crime. This cost not only involves the value of the property belonging to taxpayers and other citizens stolen and destroyed, but also the cost of policing, courts and jails. Therefore, if the sum total of such costs could be accurately determined without excessive expense, the total would no doubt be astounding.

The effect of first class street lighting on crime has been vividly set forth by a study made by Ward Harrison in Cleveland, Ohio, the results of which were published in detail in the Illuminating Engineering Society Transactions, 1921. This study of over 1,000 cases of crime in the years 1915 and 1916 in Cleveland, revealed that while crime increased 54 per cent in 1916 over 1915 ouside of the main business district, that it decreased 8 per cent in the same time in the main business district, in which a "White Way" system of street illumination had been installed early in the year 1916. Prior to this time, 17 per cent of the total crimes were committed in the business district which contained only 1 per cent of the total street mileage of the city.

Standard Street Lighting Practice

The desirability of establishing standard street lighting practices in at least similar geographical sections of the United States is self-evident, and though hardly within the limited scope of this particular report, the committee commends the following recommended practices as enunciated by the 1924 committee of the P.C.E.A.

Recommended Practice for an Overhead Street Lighting System

Appendix B:

(1) Lamps of less than 2,500 lumens (250 cp.) are not economical when used for street lighting. The cost of lighting is about one-third more than the next smaller size, i.e. 1,000 lumens (100 cp.) and the effective illumination two and one-half times greater.

(2) Do not use a lamp any larger in size than 2,500 lumens until a light unit of this size has been provided for each street intersection in the built-up district, for each point where a street crosses a steam railway at grade, and on a 15-times-the-mounting-height spacing along each important traffic street outside the built-up district.

(3) If the street lighting appropriation is more than sufficient to meet the conditions of (2) increase the size of light unit on important thoroughfares to 4,000 lumens.

(4) If the appropriation is more than sufficient to meet the conditions of (3), increase all the units to 4,000 lumens.

(5) If the street lighting appropriation is more than sufficient to meet the requirements of (4), install intermediate units of 2,500 lumens on all blocks of the built-up districts in length exceeding 20 times the mounting height (two intermediate units if lengths exceed 32 times the mounting heights).

(6) If the street lighting appropriation is more than sufficient to meet the conditions of (5) increase all units to 4,000 lumens.

(7) If the street lighting appropriation is more than sufficient to meet the conditions of (6) increase all intersection units to 6,000 lumens.

(8) If the street lighting appropriation is more than sufficient to meet the conditions of (7), provide a spacing of eight times the mounting height on all important traffic streets within and without the built-up district, using thereon 6,000 lumen intersection lamps and 4,000-lumen intermediate lamps within the built-up district, and 4,000-lumen lamps throughout outside the built-up district.

(9) If the street lighting appropriation is more than sufficient to meet the conditions of (8), provide a spacing eight times the mounting height throughout the built-up districts. Use 6,000-lumen lamps for all intersections, and 4,000 lumens for intermediate units.

(10) If the street lighting appropriation is more than sufficient to meet the conditions of (9), employ 6,000-lumen lamps throughout at the 8-times-the-mounting-height spacing.

Special attention is called to Item No. 2. This idea is rather a new thought to some engineers who have heretofore held the opinion that the minimum size lamps should be not less than 4,000 lumens even if it is necessary to install them at every other intersection instead of each intersection.

It has been found in actual comparison of the two plans that since it is very necessary to have a good degree of illumination at each intersection on account of cross traffic, that this could be provided fairly well with 2,500-lumen lamps at each intersection with but a relatively small increase in the cost of operation compared with that of maintaining 4,000-lumen lamps at alternate intersections, which provided very poor and inadequate illumination at intermediate intersections. This much more than offsets the advantage of the higher illumination at the intersections where the 4,000-lumen lamps were installed, as the difference in the illumination produced by the two lamps was hardly noticeable to the naked eye, due to the inability of the eye to detect accurately, without the aid of instruments, the variations in intensity of illumination involved in the comparison.

A Street Light for Every Intersection

An interesting and perhaps valuable psychological effect upon the public of this idea of a 2,500-lumen lamp at each intersection has come under the personal observation of the chairman of your committee.

In the city in question the minimum spacing of the 4,000-lumen street lights outside of the business district has been two blocks until recently. The power company offered to install 2,500-lumen lamps at such intersections where there were series circuits already in place, and to replace a like number of 4,000-lumen lamps with 2,500-lumen lamps at adjacent intersections, provided the city would pay the additional cost of operation of the two 2,500-lumen lamps as compared with that of the one 4,000-lumen lamp based upon the company's established rates for the respective lamps. These rates, by the way, produce an equal percentage of return upon the investment for both sizes of lamps.

After thorough study and observations of trial installations the proposal was accepted by the city, and so enthused did the city officials, newspapers and general public become with the idea of "a light at each intersection" that the council unanimously and without any opposition included in the 1928 budget an appropriation for city lighting of $26,000 as compared with the 1927 expenditure of $19,555.73, an increase of 33 per cent.

The slogan, "A street light for every intersection," seems to have sprung into being in the minds of nearly everyone, and will probably be carried into realization in due time, thereby providing a much more satisfactory system of illumination for the city and 50 per cent to 75 per cent increase in revenue for the company.

Improvement District Financing Method

The most successful method of financing street lighting recently devised, particularly for high intensity "White Way Lighting," has been by the means of creating improvement districts. The extensive white way street lighting program now under way in the City of Portland, Ore., is being carried out on the "Local Improvement District Plan."

In 1925, a charter amendment was voted by the people, granting the City Council the power and authority to install, operate and maintain special street lighting systems upon petition of the property owners and providing for the manner of paying the costs. The new section to the ordinance, which explains the plan in detail, reads as follows:

Section 338. Whenever the owners of fifty per cent or more in area of the property within any district make and file with the auditor a petition to establish a special lighting system within such district, the council shall have the power and authority to install, operate and maintain a special street lighting system or systems on any street or streets, or any part or parts thereof within said district, and to furnish electrical current for the lighting thereof, by awarding contracts therefor and to provide for the payment of the cost of original instllation and the operation and maintenance and the furnishing of electrical current for the lighting thereof by the levy and collection of local assessments on property benefited thereby. Whenever any such system is to be installed, operated, maintained and/or lighted at the expense of property benefited and to be assessed therefor, the council shall take proceedings similar to those required for constructing the same street improvements; and the method of making assessments and collecting the same as is or may be provided in the Local Improvement Code relative to street improvements, shall apply, including the right of remonstrance and the right and privilege of bonding the original cost of installation, the original and subsequent cost of operation and maintenance and/or furnishing electrical energy for the lighting thereof for such period of time as may be fixed by the council, not exceeding five years.

At the expiration of any such or subsequent period, the council shall have power and authority to continue the operation, maintenance and lighting of any such special street lighting system or systems and to award contracts for the furnishing of electrical current for the lighting thereof, and to pay the subsequent cost therefor in the same manner as is provided for original construction, operation, maintenance and/or lighting.

In the event the privilege of bonding is exercised, the property owner bonding shall pay all assessments in ten semi-annual installments with interest, and all bonds issued by the council under the provisions of Section 278 of the charter for the foregoing purposes shall mature in five years from the date thereof.

Assessment rolls are made up in the assessor's office with the complete costs prorated to the property owners according to benefits accrued.

All plans and specifications for the installations are prepared by the city engineer and are let out for competitive bid. In most of the projects let to date the installation and the "operation and maintenance" have been let by separate bid.

The regular city form of street improvement contract is used between the city and the successful bidders. Non-applying parts of the form are struck out and other clauses inserted as might be required for the particular job.

This general plan of installing and financing street lighting is very satisfactory both to the people and to the utility companies, and several miles of high intensity "White Way" lighting has been installed and put into operation under this plan.

Highway Lighting

Very little progress has actually been made recently in the territory of this association in the actual installation of highway lighting as far as the committee has been able to learn.

There seems to be no disagreement of opinion as to the proper specifications for such lighting the principal features being:

Lamp—2,500-lumen series.
Fixture—Two-way special highway.
Spacing—300 ft., limits 250 to 400 ft.
Height—30 ft., limits 25 to 40 ft.

One estimate of such a system including cost of poles is $1,700 per mile. This seems very small indeed compared with the cost of paving, ranging from $25,000 to $40,000.

According to data published by A. H. Hinkle in the March, 1926, issue of "Roads and Streets," relative to auto accidents on the state highway system in Indiana for the year ending Sept. 30, 1925, 54 or 7 per cent of a total of 767 accidents were due to glaring headlights. Out of a total of 654 accidents involving personal injuries there resulted 103 deaths or 15.7 per cent of the total number of accidents. Therefore we may assume that 15.7 per cent of the 54 or nearly 9 deaths resulted from glaring headlights to say nothing of the 529 persons who were injured, and the damaged property. The state of Indiana could no doubt afford to pay several thousands of dollars per annum to eliminate a loss of that magnitude.

The committee has found record of abstract references to highway lighting installations in the East, but no specific information has been obtained to date with the exception of that relative to the installation on the ideal section of the Lincoln Highway which has been published in many publications during recent years and hence no reference to same is made herein.

Several initial installations are being seriously considered on the Pacific Coast and may materialize in the coming year and it is hoped that next year's committee may have something definite to report along this line.

Following is an extract from a report from G. H. P. Dellmann, vice-chairman of the P.C.E.A. street lighting committee, 1927, addressed to the committee in response to its request for progress to date in highway lighting in California.

We have put a proposition up to the Highway Commission of lighting the highways for the sum of $780. per mile per year, providing they enter into a five year contract for lighting.

This proposition was made after a survey was made of the various power companies' rates, and their willingness to serve such highway lighting. It was not proposed to install standards along the highways, but to use existing pole lines where they exist and build new lines where they do not.

In this way the power companies would own all of the equipment, merely supplying a lighting service along the highways. It was planned to use a special type of highway unit, but this was to be discretional with the power company installing the job in a particular section.

These units were to be 250 cp., mounted 30 to 35 ft. to light center and spaced 250 ft. apart; this means approximately 22 units to the mile.

This proposal was presented to the Highway Commission of California, but no definite action has been taken by them as yet. But we hope that we can stir up sufficient enthusiasm soon so that at least a portion of our highways will be taken care of.

Ornamental lighting with underground construction was not considered, as it would be too difficult to put over, because of its costs.

Under the plan we are working on the power companies would bear all the construction cost and the Highway Commission would pay the monthly rentals, or, as stated before, $780 per mile per year.

Conclusion

In closing we wish to call attention to the Street Lighting Service Manual which the national committee hopes to have available by June of this year.

According to the outline of the data proposed to be contained in this manual, everyone having the responsibility of promoting street lighting will want a copy of this manual for reference.

Merchandising Bureau

General Merchandising*

The mechandising committee has chosen as the subject of its report, "The Sale of Small Appliances."

Certain information has been gathered from member companies of the Northwest association which proves that in general the sale of small appliances has been neglected. These statistics are a part of this report.

Believing that member companies are interested in increasing the number of small appliances on their lines the committee suggests nine ways in which small appliance sales may be stimulated.

Survey of Small Appliances Sold

Questionnaires were sent out to all member companies and complete reports were received from fifteen. All usable data contained in these questionnaires have been tabulated and consist of the sales, per thousand meters, of ten small appliances from the records of the fifteen member companies. These data have been tabulated in four columns, the names of the appliances, the average sales per thousand meters by member companies reporting, the highest reported sale per thousand meters by member companies reporting, and the lowest sale per thousand meters by member companies reporting. A fifth column has been added to the tabulation for comparative purposes which shows the highest sale per thousand meters made by the winners of the Hurley award. The tabulation follows:

TABLE I—Sales of Appliances per One Thousand Residential Meters.

Appliances	Average all Companies Reporting	Sales per 1,000 meters, High	Sales per 1,000 meters, Low	Winners Hurley Award
Curling Irons	5.14	40.0	1.1	22.18
Fans, desk	2.63	8.7	0.1	34.46
Grills, etc	5.71	17.5	0.7	11.86
Heating pads	3.05	6.1	0.4	6.02
Heaters, room	7.95	12.9	2.3	12.32
Irons	25.13	48.8	3.0	88.94
Lamps, floor and table	6.75	21.5	0.7	51.37
Percolators	11.54	27.5	2.0	21.70
Toasters	13.30	28.5	2.6	12.02
Waffle Irons	21.38	42.0	2.7	5.71

It will be noted from a study of the tabulation that the average sale in the Northwest is higher than the winners of the Hurley award on two appliances—toasters and waffle irons. The average sale of the other eight appliances in the Northwest varies from 6 to 50 per cent of the sale of these appliances by the Hurley award winners. The variation between the highest sale per thousand meters of any one appliance in the Northwest and the lowest sale per thousand meters in the Northwest is wide. Also the variation bgetween the average sale of the small appliances in the Northwest and the highest is nearly as wide.

The committee believes that a study of this tabulation will prove that in general the sale of small appliances in the Northwest is unnecessarily low. The committee believes also that from a study of the highest sales per thousand meters in the Northwest that it is evident some company, of those reporting, has already done an excellent job on most of the appliances tabulated.

Means of Stimulating Sales

There are many ways in which our small appliance business can be increased and your committee offers the following suggestions to member companies:

1. **Display and Advertising Methods.** To successfully merchandise small appliances requires the installation of considerable display equipment inasmuch as this class of merchandise does not show to best advantage without velour, pedestals, window fixtures and proper showcases. Showcases should be arranged in strategic points in the store. Small tables, for demonstrating small appliances, should be provided, should be placed at points where people must pass, and be fully equipped with convenience outlets to facilitate demonstrations. Demonstrations of the small appliances should be made at least during the bill paying period. Window displays, tying in with the demonstrations inside the store, are necessary.

While it is impracticable to schedule heavy newspaper advertising in promoting small appliance sales, other methods of advertising are available at reasonable cost. Bill stuffers may be sent out with statements at small additional cost. The backs of envelopes carrying current bills can be imprinted most reasonably. This form of advertising has proven effective.

In some instances broadsides may be mailed independently, providing the total cost of the broadside and postage is not prohibitive.

When a major campaign is being conducted simultaneously with a small appliance campaign, a portion of the advertisement promoting the large appliance may be blocked out and used to advertise the small appliance. This can be done without increasing the advertising schedule of the large appliance and it is our opinion that while it promotes the sale of the small device it helps rather than injures the advertising value of the entire space.

2. **Choosing Employees for Contact Points.** In small stores floor sales of small appliances depend to a large extent on the operating employees at contact points, such as cashiers, order clerks, etc. It is therefore important that these employees have proper qualifications for successfully handling merchandise sales as well as the routine of their regular work. Employees should not be selected for work at contact points unless they have an interest in the sale of merchandise and the ability to sell it. The committee recommends that such employees be educated on merchandise and the sale of merchandise. One hour a month should be devoted to the discussion of merchandise problems for the benefit of such employees.

3. **The Use of Operating Employees On Commission or Bonus Basis.** In general some tangible reward must be paid operating employees if they are expected to take a productive interest in the sale of merchandise. Various plans of commissions and bonuses for operating employees have been used by Northwest companies to good advantage. In fact, in some small communities where no regular sales force is employed, operating employees have successfully filled their regular positions and in addition have made sales records seldom equalled by regular sales forces in larger centers.

The use of employees on this basis for the sale of small appliances is particularly effective and recommended to member companies. We should not expect too much of them, however, but be prepared in most instances to sell the major, and more intricate, devices through our regular sales channels.

4. **Store Demonstration.** Thorough demonstration of small appliances is essential to their sale in quantity. In large communities store demonstrations can be conducted by the regular sales force, or with the aid of the manufacturer. In small communities some employee should be drafted for this work. Small appliance store demonstrations in small communities should be conducted during the bill paying period.

5. **Getting Customers Into Our Stores.** Electrical appliances fall in the class of specialties. In general people do not shop extensively for specialties. They have become educated to having specialties brought to them.

We must include among our appliances as many staple articles, for which people do shop, as possible. There are few staples in our lines of merchandise. Lamps may be so classed. A good display of lamps of all sizes should be made in each store. An efficient lamp service for customers should be maintained.

* **V. H. Moon**, Pacific Power & Light Company, chairman. **Mountain States Power Company:** Glenn Jackson. **Northwestern Electric Company:** J. B. Buman. **Portland Electric Power Company:** J. L. White. **The Washington Water Power Company:** R. B. McElroy.

The company can attract many people to its store by the maintenance of an efficient service department handling parts and accessories and equipped to repair appliances promptly.

Store demonstrations carried on in a systematic way will eventually create in the customer's mind a desire to see what appliance is being demonstrated each month in our stores.

Attractive window displays and store displays will attract people. It is important that such displays, demonstrations, etc., be conducted systematically, otherwise the drawing effect will be lost.

6. **Maintaining Appliance Repair Department.** The committee recommends that each utility store maintain an efficient, courteous appliance repair department. Such repairs should be charged for at reasonable prices but the service should be exceedingly prompt and courteous. Benefits from maintaining such a department are increased good will, customers come oftener to our stores, and appliances are kept in service.

7. **Monthly Small Appliance Campaigns.** Small appliance campaigns should be conducted practically every month throughout the year, following ideas which have been brought out in this report and which have been used previously to advantage. If such small appliance campaigns are put on concurrently with major activities, volume will not be sacrificed, the salesman will have one more article to sell with which to build up his sales, and our small appliance business will increase. During these campaigns our employees at contact points can be used most advantageously.

8. **Tying-In With Dealers.** Our appliance business should be conducted on a basis which is above reproach. While we may in a sense be competing with electrical dealers, and while we must be aggressive in our merchandising practices, if we are to succeed we should consider part of our responsibility that the aggressive dealer succeed also. We should offer him tangible assistance in the sale of electrical merchandise in any way that is economically sound. We must stay aggressively in the field and our continued presence in that field should mean more prosperity and more business for the energetic dealer.

9. **Store Methods.** When a customer has made a purchase of an appliance from us our method of handling the details of the transaction, such as accepting his money, signing the contract—if a contract is necessary—wrapping and delivering the merchandise, should be the equal of the methods used by the most successful stores in our community. Our methods of taking cash, receipting bills, wrapping material and delivering it should be systematic and prompt.

During the holiday season we can well afford to copy the methods of the other successful merchandisers by furnishing special gift wrappings and gift cards. We should make it a pleasure for a customer to do business with us.

Summary

In summing up the value of the specific suggestions made in this report it must be borne in mind that no one or all of them can make your small appliance sales grow without the fundamentals which govern the success of any merchandising institution. Our small appliance business needs more intelligent attention, it deserves more thought from those in charge of the company's business than it has received. It requires for its success more hard work than has been put into this part of our activities. We should be continually watching the operations of successful merchants in other businesses and adapting their ideas to our own. In other words, we must begin to merchandise.

Domestic Electric Ranges*

The committee has worked with the domestic electric range committee of the N.E.L.A. and furnished it with all available information that has been requested.

National Committee Program

The program of the national committee for 1927-1928, as outlined by its chairman, A. B. Collins, is principally of a pormotional nature. It is attempting to seek the proved facts and practices of those who are still experimenting—listing these facts as a guide for subsequent committees and as an example for sales managers throughout the country, especially those just undertaking the sale of electric ranges. This information is expected to form the basis of a sales manual on electric ranges, supplementing the Electric Range Handbooks now available.

The national committee will, this year, seek a wide distributon of the Electric Range Handbooks which have been so highly endorsed by the leaders of the industry; it will urge the central stations to put forth especial efforts to interest women employees in the use and sale of electric ranges; it will request the women's committees to promote the use of ranges in women's clubs, schools, universities, etc.; and it will also bring to the attention of all central stations the outstanding values of an electric range—forming the backbone of the electrified home and laying the foundation for other electrical appliances.

The national committee is to be commended for the work it is doing in helping to popularize the electric range in the home as well as with the central stations. This committee heartily endorses its program and calls the attention of the companies in this geographic division to the value of the information they will obtain from that program.

The Range as a Revenue Producer

The electric range is not only the most practical and revolutionizing appliance for the home, but it is one of the best load builders and revenue producers for the central station, and should be featured above all other appliances. To stress the value of the electric range as a profitable load and revenue builder, your committee gathered data on ranges in service from six member companies in the Northwest Geographic Division. These six companies report a total of 66,938 electric ranges in service on Jan. 1, 1928. These ranges are bringing a total annual revenue of $2,677,520 based on $40 per range per year. Of the total number of ranges reported in use, 15,265 were sold during 1927. On the same basis these ranges will add an annual revenue of $610,600. These figures are shown with a hope that the member companies will fully realize the value of the electric range and continue vigorously to promote the sale and popularity of this revenue producer.

The committee feels that member companies in the main are aggressively pushing the sale of electric ranges and these few words of caution are offered as a suggestion that none of our companies will lessen their efforts in the belief that this valuable business will continue to come with less promotional work on their part.

Survey of the College Laboratories

The committee has started a survey of the electrical equipment used by the students in the various colleges and universities in this geographic division. This work has been undertaken with the idea in mind that all laboratories should be equipped with the very best electrical equipment on the market. In this way our future customers will be sold on electrical appliances. We regret that this survey has not been completed and suggest that the next domestic electric range committee devote some time to this work and make a definite recommendation to the association.

Domestic Electric Refrigeration*

An attempt has been made by correspondence with the various members of this committee to gather as far as possible the local color from all parts of the Northwest pertaining to electric refrigeration. Facts brought out at the midwinter conference held in Portland, have also been studied and particular study has been made of last year's report on this same subject.

It is interesting to note that our problems today in general are what they were a year ago, the exception, of course, being that great progress has been made along all lines, including sales, servicing and rates, which were the outstanding matters of importance a year ago in the refrigeration field, and the committee can think of no better way of treating this subject this year than by following the general subdivisions treated in last year's report.

Sales

In last year's report appeared the following sentence: "At this stage of development domestic electric refrigeration is purely a sales problem." This is even more true twelve months later as the vast improvement in manufacture of practically all of the standard lines has eliminated a great deal of the distressing service difficulties, with the result that all interested, manufacturers, central stations and dealers, have more enthusiasm in the promoting of volume sales than they have ever had before.

Up until about a year ago, the changes due to rapid development of the art tended to kill sales enthusiasm, as the servicing expense was either high, or companies selling refrigerators feared that it would be high. Fortunately, with another year of history, the methodical ironing out of structural defects and the development of new models superior to the old, have resulted in a product which is giving only a small percentage of the

* **R. B. McElroy,** The Washington Water Power Company, chairman. **Idaho Power Company:** L. W. Brainard. **Northwestern Electric Company:** J. B. Buman. **Pacific Power & Light Company:** V. H. Moon. **Portland Electric Power Company:** J. L. White. **Puget Sound Power & Light Company:** R. W. Clark. **Utah Power & Light Company:** R. M. Bleak.

* **H. M. Ferguson,** Utah Power & Light Company, chairman. **Idaho Power Company:** L. W. Brainard. **Portland Electric Power Company:** C. C. Crawford. **Puget Sound Power & Light Company:** R. W. Clark. **The Washington Water Power Company:** C. L. Hoffman.

former troubles, and sales people can rightfully enter into their campaigns with the enthusiasm necessary for good results.

It is noticeable that the early difficulties in sales work have largely disappeared. The committee refers particularly to destructive competition arising out of the tendency of one faction to point out defects and dangers of other makes of refrigerators. It is very noticeable now that little of this sort of talk remains, and all agents in the field seem to be waking up to the fact that there is plenty of business for all concerned, and the greatest volume will be secured if competitors will continue to sell electric refrigeration rather than the superiority of their own particular makes with slighting reference to competing articles.

From the sales viewpoint, this is probably the most encouraging outlook, as all companies interested in refrigeration sales, up until a year or two ago, found themselves spending entirely too much time defending their products against the attacks of competitors, with not enough time left for the actual sale of the idea.

It is also noticeable that less reference is made to competition with the mere ice bill. This early tendency, of course, tended to cheapen the whole mechanical refrigeration idea, and we probably owe it very largely to the early users of electric refrigerators that the advantages, due to better food preservation and its effect on health, were brought into the general discussion. It is probably true that today the purchase of one of the many beautiful boxes on the market swings more around the obvious advantages and the general desire to own such equipment than it does around the earlier arguments of saving in ice bill, etc.

It becomes more evident the further we get into this problem that the advantages of electric refrigeration do not have to be sold to the ordinary housewife, but what is necessary is to develop an attractive box with noiseless machinery and the minimum amount of annoyance due to frequent service calls. These things have been worked out in a surprisingly short time when we compare the refrigerator with other major electrical devices and their history.

There is still a sharp division between companies as to proper method of marketing refrigeration. Some of the central stations still believe that the selling should be left entirely to manufacturers and their dealers with the central stations merely co-operating in the way of advertising and display. Other companies believe that central stations should do this job exclusively, and between these two extremes the Northwest territory and the country generally will show all sorts of modifications. This situation the committee believes will work out through a natural process of evolution, and not through attempts on the part of the member companies, or the association to change the minds of companies disagreeing with any standard plan. Local conditions in our territory have a great deal to do with the sales plans, it being obvious that the plan for a large city cannot be followed exactly in covering scattered country territory.

It seems to be a very general opinion that the larger commercial installations in restaurants, hotels, etc., should continue to be left to the manufacturer and his agent as this is a job requiring highly specialized engineering skill and few central stations would care to develop such men for a few jobs to be handled. However, in the domestic field, which is fast becoming standardized as to equipment, the feeling prevails that the central stations and dealers are better able to handle this phase of the work.

Servicing

This whole matter as judged by the midwinter conference and the reports of member companies is still in a somewhat chaotic condition, but your committee feels that servicing plans are standardized as nearly as we have any reason to expect for a job of such magnitude, and one that has swept the country in such a surprisingly short time. Continual improvement in manufacture will tend to reduce the service problem, and while costs in some sections have been out of proportion to the revenue obtained, we feel that a little patience is in order at this time based on the much more distressing period we passed through when the electric range was being brought up to its present state. Even the humble flatiron, which is taken for granted today, had its difficulties in the early stages, and we have no reason to expect that a phenomenal development such as the refrigerator, both in detail of manufacture and in sudden volume of business, should be free from its share of expense which goes with the introduction and development of any worthwhile mechanical device.

Here again, it is encouraging to note the spirit of co-operation between the manufacturers, central stations and dealers, all sensing the problem in detail and working faithfully in the perfection of the product and its application.

Rates

This is a subject which cannot be treated generally over the entire Northwest section as power costs, conditions of service, etc., vary so widely that the committee feels that this question can well be left to the individual central station to work out as best fits the local conditions.

Previous studies have indicated the danger of making sliding scale rates without due thought to what may be added to the lines, but sad experiences along this line have, we think, duly warned all officials and rate making departments, so that similar mistakes will not be made solely in the interest of simplicity of rate structure, which while highly desirable from a sales standpoint can also through carelessness be made destructive of earning power of the electric property.

The committee feels that there is no serious difference of opinion between the rate makers and the salesmen on what is desirable, and rates covering refrigeration in the Northwest are slowly but surely taking the form which will aid the salesman in his activities, while at the same time obtaining as nearly as possible what the service is worth and what it costs the central station to render such service.

Power Bureau

Commercial Cooking*

The commercial cooking committee has adopted as the theme of its report for the year 1927-1928, (a) an endeavor to stimulate interest among company executives in the commercial cooking field, (b) to stress the necessity of rates to take care of commercial cooking promotion, and (c) to present data relative to the kw.-hr. cost per unit of work done.

Last year's committee's report dealt with the dependability of the commercial cooking load to the central station, its possibilities, and some of its sales characteristics, and was modeled after the national committee's suggestions. This year, the national committee confined its activity to fostering cooking schools by member companies and to making an investigation of traveling ovens. It was not thought desirable to conduct schools here in the Northwest Division, but several of the member companies have sent representatives to the schools conducted in the Middle West. It is heartily recommended that each member company appoint some one of its employees to promote commercial cooking in their territories.

Five member companies of this association have men devoting full time to commercial cooking promotion. Table I is made up from data obtained from four of these companies and warrants some discussion.

The merchandising sales have increased in 1927 over 1926 due to the activity of those men devoting full time to commercial cooking sales work and the promotional work which the manufacturers have given to this field. The original plan of securing the business was for the central station to merchandise commercial cooking apparatus direct. However, it has been found that if the merchandising is carried on through the hotel supply houses better co-operation and better results from sales may be obtained. This is due to the contact which the hotel supply houses have with the trade and it is suggested that the central station representatives offer to the supply houses all their co-operation, both in promotion and sales. It will be noticed that to date the best

* **R. W. Faville,** Northwestern Electric Company, chairman. **Idaho Power Company:** L. W. Brainard. **Portland Electric Power Company:** A. B. Chambers. **The Washington Water Power Company:** C. L. Hoffman. **Westinghouse Electric & Manufacturing Company:** C. L. Weaver.

TABLE I—Commercial Cooking Data.

	Washington Water Power Company		Portland Electric Power Company		Idaho Power Company		Puget Sound Power & Light Company	
	(10 Mo.) 1926	(12 Mo.) 1927	1926	1927	1926	1927	1926	1927
1. Total sales of merchandise	$6,597.24	$13,015.75				$10,228	$34,833	
2. Merchandise profit	List		Sold through jobbers		List			
3. Cost to obtain business (per k.w.)	$6.79	$5.37	$4.60	$3.23				
4. Connected load (k.w.)	350	536	402	769		279	1,070	
5. Yearly revenue	$9,703.00	$15,735.00	$12,060.00			$25,240	$32,106	
6. Total No. installations	62	69	27	44		65		
7. Average rate charged		$0.016	$0.024	$0.02		$0.0254		
8. No. prospects		200		160		250		
9. Which type has proven best prospect: restaurant, bakery, hotel	Bakery Rest. Hotel		Bakery Rest. Hotel		Bakery Rest.			
10. Competition offered	Gas Hard fuel Oil		Gas Hard fuel Oil		Hard fuel Gas			

prospect has been the bakery with the restaurant in second place. However, there has been a steady increase in restaurant prospects and sales so we may look for a growing field in this line.

Rates Should Encourage Use

There has been considerable talk relative to the rates charged for commercial cooking. The companies reporting are serving large metropolitan cities. However, the rates, as established in the smaller towns, have been prohibitive of any large development in this class of load.

To overcome the cost of service and to assist in the promotion of commercial cooking, and to develop the load in smaller towns, the Pacific Power & Light Company has recently made effective a new rate called the "Commercial Cooking and Heating Rate." The only restriction to this rate is that the customer must remain off during the peak load period. The rate is as follows:

Availability—Optional with commercial cooking and heating for bake ovens of not less than 10 kw. and for small motors and appliances used in conjunction with bake opens where connected load of such appliances does not exceed 15 per cent of the baking equipment. Customer agrees not to use service during peak load period which period specified by the company shall not exceed four consecutive hours in any 24-hour period.

Rate—Wright demand and block meter.

Base rate, covering first 60 kw.-hr. per kw. of demand 3 cents per kw.-hr. for first 1,000 kw.-hr. 2.5 cents per kw.-hr. excess.

Secondary rate for excess over first 60 kw.-hr. per kw. of demand, 2 cents per kw.-hr. for first 1,000 kw.-hr., 1.5 cents per kw-hr. excess.

Determination of Demand—One hundred per cent of connected load except that for installations of two or more baking ovens, or for one oven of over 20 kw., the demand may be measured by demand meter, the demand for billing purposes being the highest demand during preceding 12 months, or by test during peak load. (1 hp. considered equal to 0.83 kw.)

Prompt Payment Discount—None.

Minimum Charge—$1.50 per kw. of demand.

The advantage of this rate is very evident from the standpoint of the system load curve; and it also has the advantage of a graduated step so that the three cents top rate takes care of the smaller appliances such as waffle irons and coffee urns, while the two cents step will take care of the medium size bake oven installations. With the larger installation, of course, most of the energy is used at the 1½-cent rate. With such a rate in effect central station energy is in line with competitive fuels and with proper promotion the company can expect a very attractive revenue in the commercial cooking field.

The Idaho Power Company recently has adopted a rate for commercial cooking but as yet the rate has not been published.

Unit Costs Are Important In Selling

With a favorable rate for the promotion of commercial cooking, it is necessary to obtain unit costs so that the baker may determine the advisability of utilizing electricity for his baking medium. A. B. Chambers, Portland Electric Power Company, has obtained for the committee the cost per loaf of bread in various sizes of ovens. This report will include the results of his tests made on a 640-loaf deck oven, a 120-loaf deck oven and a traveling oven with a capacity of approximately 1,000 one-pound loaves of bread per hour.

The first oven tested was a two-deck oven, with 640-loaf capacity, 60 kw. connected. This oven was cold and had not been in operation for three days at the time the test was made, so an excellent opportunity was presented for discovering the preheating quality of the oven. It required 1½ hours in the high heat, or 90 kw.-hr., to heat the oven to a bread baking temperature of 420 deg. It required 40 minutes to make the bake with 640 loaves, which consumed 26 kw.-hr. Three charges, or 1,920 loaves, were baked, and the actual consumption during the time of baking, not including the preheating period, was 97 kw.-hr. The total for the whole test was 187 kw.-hr., and the average rate earned by this baker was 1½ cents per kw-hr. The cost for the 1,920 loaves was $2.85, and the average cost per loaf was 1½ mills.

The next oven was a 16-kw. oven of 120-loaf capacity. It required 1¼ hours to preheat, consuming 20 kw.-hr. One hundred twenty loaves were baked in this oven in 42 minutes, consuming 9 kw.-hr. and a small fraction over. The average rate earned on this small oven was 2 cents, which we might say, in this particular case, was lower than the average. The cost of the 120 loaves was 58 cents and the cost per loaf was 4.9 mills.

These tests show conclusively the difference in operating cost between the large size and small size ovens. The fuel cost with the 60-kw. oven was 1½ mills per pound of bread baked, and with the 16-kw. oven was 4.9 mills per pound. That same difference applies as the ovens grow smaller. The rule then may be stated thus: that the cost of baking increases inversely as the size of the oven, or as the connected load of the oven decreases.

The test on the traveling oven was conducted on one of three travelers in Portland. The result of it shows that the current consumption per pound of bread baked was 140 watts and the average cost was 1.4 mills per pound. Over a week's test the total kw.-hr. consumed by the oven, from Sunday 6:15 a.m. to Saturday 4 a.m., or 142 hours, was 8,199 kw.-hr. The actual number of hours of operation during those seven days was 121¾. The cost of operation was $98.38. The hourly consumption was 67.34 kw.-hr. The average cost per hour was 80.8 cents. The average cost per pound—and this includes not only bread, but cookies, sweet dough and other products baked there—was 1.3 mills, and the average cost per retail dollar of value was 1.1 cents.

Summary of Oven Tests

640-loaf oven	60 kw. demand
To preheat 1½ hours	90 kw.-hr.
Bake 40 min.	26 kw.-hr.
Bake 1,920 loaves	97 kw.-hr.
Average rate 1½c	Cost per loaf, .0015c
120-loaf oven	16 kw. demand
To preheat 1½ hours	20 kw.-hr.
Bake 40 min.	9 kw.-hr.
Average rate 2c	Cost per loaf, .0015c Cost for 120 loaves, .58c
Traveling oven	120 kw. demand

Current consumption 8,199 kw.-hr. for 142 hr. (121 hr. actual baking).

Average hourly consumption	67.34 kw.-hr.
Average cost per hour	80.8c
Average cost per lb. goods baked	1.3 mills.
Average cost per retail dollar	1.1c.

The foregoing shows that the operation of a traveling oven is unquestionably economical if it is operated continuously. The complaints heard as to operating costs on the traveling type of oven are mainly caused by the fact that the oven is operated intermittently, and that it requires additional heating at different times to keep up the required temperature. There is another traveling oven in Portland that bakes nothing but cookies, turning out 500 dozen per hour at a cost of 5 mills per dozen.

In conclusion allow us to stress the necessity for member companies to have salesmen in the field devoting their time to the promotion and sale of commercial cooking apparatus. Previous reports have shown conclusively the advisability of this load and the benefits derived from the operation of the equipment. The manufacturers are giving splendid co-operation to the central stations and are reducing the selling expense. It is necessary to have rates for this type of equipment and its inherent qualities warrant the concessions requested by the bakers and restaurants. Competition of other fuels will retard seriously the promotion of commercial cooking unless rates reasonable to the customer are granted.

Competitive Power*

Some time ago a letter from J. E. Davidson, then president of the N.E.L.A., stated that he wished that all publicity possible be given to the work of this committee. After correspondence with H. W. Derry, chairman of the national committee, the local committee learned that it was to handle not merely competitive power problems but all major power sales problems, whether competitive or not. It was also to help in gathering and making available information on any phase of electric power application. Mr. Derry also advised that the word "Competitive" would be dropped from the committee name, and his letters are now directed to the "Power Committee." However, inasmuch as there are connittees in this division designated to study definite power applications, this committee has for the present actively considered only competitive power problems. It has, however, participated in gathering operating data and information on various power applications for the national committee.

It is the intent of the national committee to act as a clearing house for all data gathered and to make available information on any kind of power application. In this connection it contemplates compiling a new power salesman's handbook which, no doubt, will be a worthwhile accomplishment if it is kept up to date. There is much new business to be developed, and the power committee work in this division in the future should be directed toward this development as well as toward meeting the competitive situation.

Survey of Competitive Situation

In considering the competitive situation the committee asked for a report from some of the member companies indicating conditions in the territory they serve. Those reporting were the Puget Sound Power & Light Company, The Washington Water Power Company, Northwestern Electric Company and Pacific Power & Light Company. The committee regrets that this survey does not cover the entire territory of the Northwest Geographic Division, but believes it to be representative of division-wide conditions.

The findings are shown in Table I.

In view of the fact that the waste wood problem seems to be the most perplexing, the committee asked E. E. Scofield, who has been successful in securing considerable wood-working business, to present a study of the electrification of plants using waste wood for fuel. The second greatest competitive problem is that presented by the laundries. J. D. Scott has gathered data relative to this problem, on which it is difficult to get dependable data because of the physical layout within the laundry. A study of these two problems constitutes the major activity of the committee during the past year. Both papers are attached hereto and made a part of this report.

* **W. H. McMurray,** Pacific Power & Light Company, chairman. **Northwestern Electric Company:** R. W. Faville. **Portland Electric Power Company:** J. D. Scott. **Puget Sound Power & Light Company:** T. M. Gibbes. **The Washington Water Power Company:** E. E. Scofield.

TABLE I—Competitive Power as shown by Survey of the Properties of the Puget Sound Power & Light Company, The Washington Water Power Company, Northwestern Electric Company and the Pacific Power & Light Company.

Kind of Power	Business	No. of Installations	Horse-Power Installed	Reason For Use	No.
Steam	Wood working	58	31,945	Waste fuel	58
	Laundry	16	1,140	Require live steam	26
	Cannery	6	185	Require live steam	
	Clay products	3	525	When installed, electricity not available	4
	Cold storage	2	450	Infrequent Use	1
	College	1	500	.....	
	Hospital	1	175	.....	
	Biscuit Co.	1	150	.....	
	Oil company	1	20	.....	
	R. R. shops	1	25	.....	
	Rock crusher	1	100	.....	
	Total	91	35,215	.....	
Oil Engines	Cold storage	4	290	Thought to be cheaper	5
	Pumping	2	50	Electricity not available when installed	2
	Feed Mill	2	45	Use waste heat	1
	Machine Shop	1	15	.....	
	Creamery	1	20	.....	
	Total	10	420	.....	
Gas	Hoist		25	Infrequent Use	2
	Fire pump		30	.....	
	Total		55	.....	

Only installations of 25 h.p. or larger, developing their own power, were considered in this survey. The listings are here shown divided into the various kinds or sources of power development, with the total h.p. in each class and the reasons given for its use.

Electrification of Woodworking Plants

By E. E. Scofield*

Inasmuch as most woodworking plants have a supply of sawdust, shavings and refuse more than sufficient for fuel to produce their required power, it is the disposal of this supply of wood waste which generally determines whether central station power can be used. There are, of course, a great many talking points for central station service, but the cheap fuel supply is without doubt the chief factor in determining whether or not power will be purchased.

The woodworking industry as a whole has been extremely backward in the economic development of by-products from their waste. The result is, to date, the only use that has been made of this waste is for fuel. Necessarily this means that the price obtained is determined by the competition with other types of fuel and consequently is low.

Where there is no market whatever for the woodworking plant refuse and the disposal of such refuse becomes an item of cost, it is generally uneconomical for the plant to purchase power. For the purposes of this paper, it is assumed in the following analysis that there is a market for this refuse.

There are two general classes of power transmission used in woodworking plants: steam engine with line shaft drive to machines and individual motor drive. An analysis is made as follows of a typical plant for each of these classes.

Steam Engine and Line Shaft Drive

General Data.

Assume planing mill with an output of about 75,000 b.ft. per 8-hour shift. On basis of 0.6 cord of shavings and sawdust per M.b.ft., the refuse available is about 1,150 cords per month.

Cost of Steam Engine Drive

Equipment

Boiler and boiler house in place	$4000
† 300 hp. Corliss Engine	1500
Installation of engine	1000
Line shaft and belting	2500
	$9000

Fixed Charges

6	per cent Interest
5	per cent Depreciation
2	per cent Taxes and Insurance
5	per cent Maintenance
18	per cent Total
18	per cent of $9000 = $1620 per year.

* Report of competitive power committee

† Low cost of engine due to great number of second-hand ones available.

Operating Expense

(a) **Fuel**

Assume average load on engine is 200 hp.

Assume 45 lb. steam per boiler-horsepower-hour.

Assume 1 cord of fuel will evaporate 4,900 lb. of water

Therefore 200 hr. × 200 hp. × 45 lb. = 1,800,000 lb. water used per month by engine

Adding 11 per cent for losses through auxiliaries and safety valves, the total is 2,000,000 lb. water per month.

Therefore, fuel used is $\frac{2,000,000}{4,900} = 408$ cords per month or 4,900 cords per year.

(b) **Water**

2,000,000 lb. is 240,000 gal. at 10c ..... $ 24

(c) **Labor**

1 Engineer—fireman, per month 200

(d) **Miscellaneous Supplies**

Oil, waste, compound, etc., per month 30

Total operating cost per month with free fuel $254

Annual Cost Steam Operation with Free Fuel

Operating costs—12 months	$3,048
Fixed Charges	1,620
Total	$4,668

Electric Drive and Purchased Power

Cost of Electric Drive and Purchased Power Equipment

Wiring and 385 hp. in motors installed	$6,500
300 kva., 13,200/440 volt substation	2,700
Total	$9,200

Fixed Charges

6 per cent Interest
5 per cent Depreciation
2 per cent Taxes and Insurance
2 per cent Maintenance

15 per cent Total
15 per cent of $9,200 = $1,380 per year.

Monthly Power Requirements

(a) **Demands**

70 per cent of 385 hp. is 260 kva. demand
260 kva. at 70 per cent p.f. is 182 kw. demand

(b) **Kilowatt-Hours**

Assume average load is 70 per cent of 182 kw. or 127.5 kw.

At 8 hr. per day 25 days per month, then
monthly load is 25,500 kw.-hr.
annual load is 306,000 kw.-hr.

Comparison Steam Engine vs. Purchased Power

Annual cost steam engine drive with free fuel	$4,668
Annual cost central station service with free power	1,380
	$3,288

Discussion

Evidently there is a balance of $3,288 which the woodworking plant can afford to spend for purchased power, even though the fuel costs nothing. Therefore on the basis of free fuel $3,288 divided by 306,000 kw.-hr. is 1.075 cents per kw.-hr. that could be paid for power. Obviously this is much too low a rate to give such a load. Most power companies in the Northwest would have to charge about 2 cents per kw.-hr. On this basis, the shavings and sawdust would have to be priced as follows:

306,000 kw.hr. at 2c	$6,120
Fixed charges	1,380
Total cost purchased power (annually)	$7,500
Cost steam engine drive	4,668
Therefore annual revenue from waste	$2,832

or $2,832 divided by 4,900 cords = $0.58

Evidently the wood waste would have to sell for 58 cents per cord at the bin in order to sell this plant power at 2 cents per kw.-hr.

Power Plant vs. Purchased Power

It is assumed that the woodworking plant is all electrified and is considering either purchasing or making its own power from the mill refuse.

Load Conditions

637 kva. demand
932,800 kw.-hr. annual load

Power Plant Costs

(a) Equipment

Building	$10,000
Spray Pond	5,000
Boiler	20,000
Stack and Fans	2,000
2—500-kw. turbines installed	35,000
Water storage	4,000
	$76,000
Contingencies	4,000
	$80,000

(b) Fixed Charges

6 per cent Interest
5 per cent Depreciation
2 per cent Taxes and Insurance
5 per cent Maintenance

18 per cent Total
18 per cent of $80,000 is $14,400 annual fixed charges.

Operating Expenses

(a) **Fuel**

Assume overall water rate of 23 lb. per kw.-hr.
Therefore 932,800 × 23 lb. = 21,450,000 lb. water per year

Losses	2,150,000 lb. water per year
Total	23,600,000 lb. water per year

Assume 1 cord waste will evaporate 4,900 lb. water
Therefore 23,600,000 divided by 4,900 is 4,815 cords per year.

(b) **Water**

2,150,000 at 10c ..... $ 215

(c) **Labor**

2 men—1 shift 3,600

(d) **Miscellaneous Supplies**

Oil, waste, etc 1,000

Total annual operating cost with free fuel $4,815

Annual cost power plant with free fuel operation costs	$4,815
Fixed charges	14,400
	$19,215

Comparison Power Plant vs. Purchased Power

It is evident that the only expense for purchased power would be the cost of a substation. This might cost about $5,000. The fixed charges therefore would not be a serious consideration and can be neglected in this comparison.

Therefore the power would have to sell for $19,215 divided by 932,800 kw.-hr. or 2.04 cents per kw.-hr.

Discussion

It would seem that such a rate could be offered by most power companies in the Northwest for this business. Such a comparison looks very bright for the "purchased power" side, but it must be pointed out that there might be a demand for process steam and the cost of disposal of the waste might be an item of expense, all of which would detract from these figures.

Summary

There are many grades of waste produced by woodworking plants, all of which differ considerably in their value as a fuel. We have found that the shavings and sawdust from such woodworking plants as planing mills, box factories, match block plants and frame factories will on an average evaporate 4,900 lb. of water per cord. Sawmill waste has not been used as a commercial fuel in the Spokane territory until recently and there are no data available on the value of this type of fuel. Since our timber runs heavy to pines, it is probable that the heat content of our sawmill waste is considerably less than that of the Coast mills where the principle cut is fir.

Sawdust and shavings have been used very successfully here for a number of years, and now there exists during the winter, a shortage of such fuel. The great problem of handling this fuel is the summer storage. The average price paid here for sawdust and shavings ranges from 50 to 75 cents per cord at the plant, and the delivery price about $1.75 to $2. This obviously leaves a small margin for summer storage. However,, this fuel is being handled here profitably by several people and the use of it has proved very satisfactory to both the mills and the consumers.

The Laundry Load

By J. D. Scott*

In the Portland territory there are some fifteen laundries which, if completely electrified, would require an average installed capacity of 125 hp. and consume perhaps 8,000 kw.-hr. per month each. There are of course a number of smaller laundries and at least two much larger. Altogether there is some 2,000 hp. potential laundry load with an estimated monthly consumption of 120,000 kw.-hr.

At the present tariff rates applying here, this means that the largest laundries could earn a net rate of 2 cents per kw.-hr. and less, the average size laundry between 2½ to 2¾ cents per kw.-hr., and the small

* Report of competitive power committee

laundry not less than 3 cents per kw.-hr. Experienced laundrymen state they cannot afford to purchase central station power for all purposes unless they can net a rate of 1½ cents per kw.-hr. or less. Some of them put the figure at 1 cent. We assume that this situation is typical and applies with equal force to any other city in the Pacific Northwest.

Only two or three of the largest laundries are buying all their power and lighting from the central station companies. The average condition is for the laundry to manufacture its own power either by an engine-driven generator, or direct engine drive to line shafting. Frequently both methods are used in the same laundry. A small engine generator set for lighting and electric iron service is also often installed. In addition to the above, the laundry buys "standby" lighting and in a few cases "standby" power for its motors from the central stations who require only a low minimum charge for this service. This standby service is used by the laundry only after regular working hours—Saturday afternoons and the like, and seldom exceeds $25 to $30 per month. Naturally under such conditions the net rate paid is high, about 5 cents per kw.-hr.

The stumbling block to getting all of the laundry business, other than considerations of rates, is the necessary use in the laundry of high pressure steam. Originally it was thought that clothes could not be washed clean without very hot water, 200 deg. F. and over. Now it is known that very hot water actually cooks certain kinds of dirt into the fabric and much of the washing is done with water at 140 deg. to 150 deg. F. Wash water is generally heated by exhaust steam from the engines but there is no reason why it could not be heated direct if the necessity for high pressure steam could be done away with.

Many laundries operate steam cleaning and pressing departments to handle clothes, robes, rugs, blankets, draperies, etc., for which some high pressure steam is required. But those that have no such departments claim they must have at least 125 lb. of steam pressure for the operation of their large mangles, presses, shirt and collar machines, etc. In this connection, a prominent laundryman stated recently that the electric hand iron was soon going out of business in modern up-to-date laundries. The new presses now being manufactured take the place of many hand irons and finish the work more quickly—another case of high pressure steam.

So long as this need for steam exists, the laundryman figures his engine as a reducing valve for hot water making and any mechanical or electrical power he gets out of it is considered as so much "velvet." Of course, this assumption is not exactly true, but even after allowing interest, depreciation, maintenance, rent for floor space on the engine generator set and 5 to 10 per cent extra fuel for heat losses in the engine, it is not difficult to see where the laundryman's demand for low-priced electricity comes from.

Our conclusion in this territory is that we do not want to go into the business of making special rates to different classes of small industry. Once started, there is no end to it and it is exceedingly hard to justify against claims of some other classes of business. For example, the bakery, the dairy, the battery shop, the small ice plant, and the lynotype shop can all with even greater justification claim a 1-cent flat rate if the laundries get it. Nowadays rates to the general public must be made presumably on the "cost to serve" theory. Rates based on the "value of service" to the user, while unquestionably right under certain conditions, make for bad public relations and stir up all kinds of grief for the central station, particularly when applied to the smaller classes of industry.

We will get more of the laundry business when rates to all classes of power customers go down simultaneously. Until then, give them at tariff rates all the standby they wish to take.

Industrial Heating*

The committee presents the following statement about the industrial heating load, giving its opinion as to the extent of the possible load, the means by which the load can be secured, and recommending a survey as the first step toward determining whether or not the utility companies desire to make the effort to develop it.

No Development Without Specialized Effort

When electric utilities first began operating in this country, their efforts were confined almost solely to the sale of lighting and the operation of street railway systems. As time passed and substantial inroads were made in the field of the gas lighting business, the idea of electric power service began to develop. Through the operation of trained salesmen, steam and gas engine driven factories were converted to electric motor drive until now this represents the power companies' largest energy consuming load.

At the time electric ranges were first introduced, considerable doubt was felt by many utility executives as to their ultimate success as profitable load-builders. Now, not only is there no doubt, but all progressive companies keep a corps of special salesmen who devote their time exclusively to the sale and installation of domestic ranges. Within the last few years, these same companies have put on trained men who do nothing else but further the cause of electric bake ovens and commercial cooking.

The phenomenal growth of street lighting, of better home, office, and factory illumination, is largely accounted for by the illumination engineers, men employed by the utilities to build up this class of load and increase the revenues therefrom. The lesson to be drawn from these records is that no development of a particular class of load building is possible without specialized effort and considerable pioneering expense on the part of the utility. If we really want the load, we must be prepared to develop it ourselves and not just wait for it "to happen."

Greatest Potential Load Building

If the reports issued by special committees of the N.E.L.A. in recent years are to be taken at face value, industrial heating is by far the greatest potential load builder facing the electric utilities today; a load so large that the much touted cooking load is in comparison a mere drop in the bucket.

Industrial heating committees of the Northwest Electric Light and Power Association have in previous years outlined the great possibilties for industrial heating loads in this territory and have suggested means of obtaining them. Why, then, has so little effort been made in this direction? Simply because executives are not "sold" on the belief that there is enough net profit in the load to justify a heavy pioneering expense and another specialized department of their already large sales organizations.

Accurate Survey Is First Step

It is the opinion of your present committee that a rehash of the industrial heating prospects in the Pacific Northwest is merely a waste of time as it will probably receive little more than waste basket consideration. No executive can be expected to pass judgment on the possibilities of industrial heating as a net revenue producer, without having an exact estimate of what those possibilties are. There is but one way to procure such an estimate, and that is by an intelligent and accurate survey of the available field served by the utility.

In June, 1926, the power bureau committee of the New York Section of the N. E. L. A. put out a splendid report detailing the exact method by which a general industrial survey should be conducted. Their recommendation was that the survey should cover not merely "industrial heating," but "power," "lighting," "refrigeration" and "vehicles." Copies of this report were distributed by the N.E.L.A. to all its member companies, but so far as we know only one utility in the Pacific Northwest followed the recommendation and that one only to a very limited extent.

In January, 1928, the N.E.L.A. published a bulletin containing a serial report of the industrial heating committee, entitled, "A Sales Plan for Developing the Industrial Electric Heating Load for Electric Service Companies." This report is all meat and no shell and we strongly commend it to the attention of all company sales managers and higher executives. The first step recommended is an industrial heating survey, after which, with the data obtained, a definite decision can be reached as to whether or not under local conditions and rates, the load is worth spending money to get. There is scarcely a manufacturing plant today but uses heat

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in some of its processes, and such heating requirements can be fairly accurately estimated or measured, so that a systematic survey will show tangible possibilities and not guesswork.

The committee this year is of the opinion that we in the Northwest should take our cue from those Eastern companies which have pioneered this field and start our consideration of developing the industrial heating load in our respective territories by conducting an intelligent survey, for until this is done most of our efforts will be confined to those few outstanding cases in which the customer voluntarily comes to us requesting the service. Even then, we are frequently not in a position to give convincing advice particularly if the heating problem involves some special features foreign to our experience.

Rural Electric Service*

This committee has had one meeting during the year, which was held in Portland on Dec. 1, 1927.

The subject of principal interest discussed at this meeting was the splendid work being done by the State C.R.E.A.'s. It was pointed out that the power companies are not making use of the findings of these committees to the extent that they could, on account of a lack of understanding by the personnel of the different companies of just what is being accomplished.

It was also pointed out that there is a need of getting the results of the investigations of these committees before the farmers. Two ways of doing this were suggested: first by issuing a loose-leaf handbook for our company agents, and, second, by schools to be conducted for our company agents.

Handbook

The handbook was to be Lefax No. 555, in which there should be information on the different uses of electricity on the farm, including the benefit to the farmer of its use, where the apparatus can be purchased, approximate cost of the apparatus, size of motor (if motor is required) and approximate cost of operation, or kw.-hr. consumption from which cost on different rates could be figured. The chairman of the committee was instructed to write to Charles F. Stuart, chairman of the National Rural Electric Service Committee and also to Dr. E. A. White, director of the National C.R.E.A., concerning the possibility of getting out such a handbook. After receiving information from both, it was decided that for the present the recent report of the National C.R.E.A. would fill the place of this handbook. This report was published in Feb., 1928, and Dr. White and his staff are to be congratulated upon this very fine piece of work. It contains pictures of different operations showing the use of electricity on the farm, much data gathered by the different state committees, a bibliography of electricity on the farm, and a list of manufacturers and dealers of farm electric equipment. This book should be in the hands of every rural representative of electric companies.

Schools for Rural Electric Service Men

Another very effective way of getting the work of the state committees to the farmers is by means of schools conducted for electric company employes who are spending all or part time in helping farmers with their electric problems.

During the past year there have been three such schools conducted in the Northwest: one at the Oregon State Agricultural College conducted by the Oregon C.R.E.A., held Jan. 23-28, 1928. There were 49 paid registrants, all of whom were employes of the different electric companies of Oregon, Washington and Idaho.

Another school was held at Seattle, Feb. 20-25, 1928, conducted by the Puget Sound Power & Light Company, in co-operation with the Washington C.R.E.A. Fourteen employes of the Puget Sound Power & Light Company, attended this school.

A third school was conducted in Spokane, Wash., by The Washington Water Power Company and the Washington committee. Details concerning this school are not obtainable at this writing.

Elements in a Farm Electrification Program

In addition to the handbook and schools, the following suggestions are made in connection with putting over a farm electrification program:

1. **Farm Rate**—A farm rate for electric service on the farm, made to fit farm conditions and farm practices is of first importance. The nature of farm work and operations is diversified. An agricultural electric load can be built only by encouraging many short-time uses. A rate should encourage diversified uses and place no severe penalty on connecting and disconnecting seasonal use equipment.

2. **New and Improved Equipment and Machinery**—There is a very great need for suitable equipment and machinery to be electrically operated, so that more manual labor can be electrified, and so that costs of other forms of energy can be reduced. This, however, is a function of the manufacturers, working in co-operation with the State C.R.E.A.'s, but each electric company should stand ready to lend its engineering assistance to experiment and trial.

3. **Demonstrations**—After a new appliance or method has been worked out, the electric companies should endeavor to get at least one sample of it in each community to use as a demonstrating model, to help sell others on its feasibility.

4. **Programs for Farmers' Meetings**—The electric company should always be ready to help the program committees of the granges and other farm organizations, by giving talks or putting on moving pictures or stereoptican views concerning the use of electricity on the farm. This activity has proven very valuable in bringing the companies and the farmers closer together, in many instances.

5. **Farm Booklets**—Farm booklets, containing descriptive material on different uses with some cost data, instructions regarding use, accounts of actual operation, and information as to where such apparatus can be obtained, are extremely valuable. There is need of these booklets, especially at fairs. The recent booklet gotten out by the National Committee on the Relation of Electricity to Agriculture serves a crying need in this connection.

6. **Advertising**—Country newspapers, farm journals and magazines, and town billboards, are excellent media for advertising the use of electricity on the farm. The appeal should be made on the basis of how electricity can be used to make larger and better crops, to reduce manual labor, or cut costs, or otherwise bring to the farmer and his family the things they rightfully want.

7. **News and Feature Stories**—The farm journals are always glad to publish stories about successful methods applied on farms, and in the comparatively new field of electrical application lies a wealth of material from which interesting stories of this kind can be written. When these stories are honestly written about actual operations by a certain farmer, they form a most effective means of spreading the information.

8. **Fairs**—Some of the fairs offer an excellent opportunity of demonstrating to many farmers the new apparatus which is being developed in connection with the use of electricity on the farm.

9. **Contacts**—Each electric company could well afford to make contacts with all agencies that are active in the development of agriculture, such as:

State and National Committees on Relation of Electricity to Agriculture.
County Agricultural Agents and Extension Service Specialists.
Experiment Stations.
Local Representative U. S. Department of Agriculture.
State Department of Agriculture.

Farm Organizations:
State and Community Heads of
Granges
Farmers' Unions
Farm Bureaus
Community Clubs
Dealers and Manufacturers of Farm Machinery and Apparatus.

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The state departments of agriculture are active in the regulatory work and enforcement of laws concerning sanitary practices on dairy farms. Electrical methods and apparatus work hand in hand with the production of better and more sanitary milk, at less cost to the producer. Dairy inspectors should be kept informed on all new developments. There is a great opportunity for co-operation here.

Companies of the Northwest That Have Rural Electric Service Departments

There is no company in the Northwest maintaining a department of itself known as the Rural Electric Service Department. However, all the larger companies have a sub-department, generally a division under the sales department, looking after this work. Some of the companies maintain full-time men, and some, part-time men. The following is a list of the companies and the men in charge of this work:

The California Oregon Power Company, J. C. Thompson, Medford, Ore.

Eastern Oregon Light & Power Company, J. P. Lottridge, Baker, Ore.

Grays Harbor Railway & Light Company, H. G. Kelsey, Aberdeen, Wash.

Idaho Power Company, Robert Beresford, Boise, Idaho.

Mountain States Power Company, H. C. Wells, Albany, Ore.

Northwestern Electric Company, F. H. Robinson, Vancouver, Wash.

Pacific Power & Light Company, George Hibbert, Toppenish, Wash.

Portland Electric Power Company, W. M. Hamilton, Salem, Ore.

Puget Sound Power & Light Company, J. C. Scott, Seattle, Wash.

Utah Power & Light Company, E. R. Owen, Logan, Utah.

The Washington Water Power Company, J. F. Farquhar, Spokane, Wash.

Rural Lines and Customers

The following information pertains to the State of Washington only:

On Jan. 1, 1928, there were approximately 4,700 miles of rural line in Washington, serving 31,000 farmers, which is approximately 45 per cent of all the farmers in the state. The 31,000 farmers do not include all the rural customers, of which there are many others falling outside the classification of "farmer."

There were seven hundred miles of rural lines constructed during the year 1927, and 5,200 farmers connected to rural electric service lines during that year.

Figures for the other states of the Northwest division are not at hand at this time.

Rural Line Extension Policies of the Northwest

Idaho Power Company—It is the present practice to use the same rates in rural territory as for urban territory, and the only difference in rural service is that brought about by the application of the rural extension rule. This provides that the company spend for distribution line extensions three times the annual guaranteed revenue. Where the cost of the extension is in excess of this amount, the customers advance in cash an amount equivalent to such excess. This cash advance, however, is in the nature of an advance payment for service and is deducted from the monthly service bill in the amount of one-third of each bill, so that in the long run the company is financing the extensions.

Portland Electric Power Company—The company finances and constructs at its expense any extension which does not exceed $60 per customer, or 2½ times the estimated annual revenue, provided the estimated annual revenue is in excess of $24 per customer.

The California Oregon Power Company—The company makes its extensions under the Public Service Commission of Oregon Order No. 941. It expends 2½ times the estimated annual revenue and the customer puts up the balance as a prepaid revenue to reimburse the company during the period before the line becomes self-supporting.

The Washington Water Power Company—The company finances the entire extension cost in every case when the capital cost of the extension is equal to or less than twice the anticipated annual revenue, and the customer finances the portion of the extension which is in excess of twice the anticipated annual revenue. This is in accordance with the established rural extension policy of the company, the greater portion of which was suggested by the Washington Department of Public Works.

Pacific Power and Light Company—1. Development period—10 years. 2. Cash equivalent to extension unit—$46. 3. Investment ratio to be used—$1.75 to $1. 4. Deficiency factor—20 per cent.

Utah Power & Light Company—The company operates under a two-to-one ratio, under which the company will spend twice the earnings guaranteed by the consumer, the balance of the cost being advanced by the consumer, but refunded for a five year period as one-third of his monthly bills.

Puget Sound Power & Light Company—The company will expend a minimum of $35 per customer, not including transformers and regardless of the amount of estimated revenue, or will expend $2.50 per dollar of estimated revenue per annum. If the construction cost, not including transformers, is more than $2.50 per dollar of estimated revenue, the company requires the customer or customers to prepay an amount that will take care of all overhead charges and operation of the excess cost. The amount of this prepayment is made up of return, taxes, depreciation, operation and contingencies for a period of fourteen years, which is termed the development period.

If the construction cost is six times the estimated revenue per annum or more than six times, the company declines to build the extension and refers the case to the State Department of Public Works.

Under the above plan the company owns, maintains and operates all extensions as a part of its general system, and the customer is entitled to the prevailing rates for service as if no extension were required.

Classification of Rural Customers

There is need for a standard classification of rural customers among all companies in the United States, so that the information and data issued by the different companies concerning rural customers will be comparable.

A suggestion for this classification is as follows:

Farmers
- Sheep and wool
- Beef cattle
- Dairy cattle
- Hogs
- Poultry
- Fur
- Hay
- Grain
- General—sugar beets, cabbage, seeds, etc.
- Orchard
- Berry
- Truck
- Flowers and bulbs

Rural residents not farmers.

Engineering Section Reports

Executive Committee[2]

Executive Committee Meetings—The executive committee of the Engineering Section during the past year has held four regular two-day meetings and two special one-day meetings. The regular meetings were alternated between Portland, Seattle and Spokane. One of the special meetings was held at Olympia, Wash., the day prior to the hearing for the establishment of clearances of overhead conductors across state highways. The other special meeting was held in Portland, Ore., in order to confer with J. O. R. Coleman from the national headquarters staff.

Neutral Problems—Mr. Coleman told of the common neutral study made in Minneapolis, Minn., by representatives from the telephone company and N.E.L.A.,

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aided by the local power company. Noise on the telephone system was of sufficient intensity to cause the telephone company vigorously to oppose further extension of the common neutral. As a result of the study and investigation, co-ordination was brought about by grounding the cable sheaths at both ends, and by the installation of some high-impedance ringers.

The common neutral system is national in scope. For this reason, as a test case, a study is being made in California to determine the costs involved in bringing about proper co-ordination. Two districts have been selected, one in San Francisco and the other at Los Angeles. Existing systems will be cut over to a common neutral, and data recorded as to conditions before and after, followed by remedial measures necessary with attendant costs involved.

Strength of Overhead Lines—A national subcommittee of the overhead systems committee has been organized to study loading and strength of overhead lines. W. G. Kelley, Commonwealth Edison Company, Chicago, is chairman of this subcommittee and in order to give this important problem the proper attention a special committee was appointed in the Northwest Geographic Division with H. H. Schoolfield as chairman.

National Committee Meetings—During the year two group meetings of the National Electric Light Association, Engineering Section, were held; one at Chicago, Oct. 3-5, 1927, which was attended by R. R. Robley, Portland Electric Power Company, and J. B. Brokaw, Eastern Oregon Light & Power Company; the other at Louisville, Ky., March 19-22, 1928, was attended by J. B. Fisken, The Washington Water Power Company, W. S. Hill, Grays Harbor Railway & Light Company, and O. L. LeFever, Northwestern Electric Company.

High Tension Testing Laboratory—The member companies of the Northwest association are greatly in need of a high tension testing laboratory. A special committee from the Engineering Secton has conferred with officials of the Oregon State Agricultural College at Corvallis and the Washington State College at Pullman as to equipment required, cost of same, and means for financing the installation.

Annual General Meeting—The fifth annual general meeting of the Engineering Section was held at Spokane, Wash., on March 8-9, 1928. There were 111 delegates registered. Much valuable information was brought out in the papers and discussions, but as the proceedings of this meeting will be published and available for members of the organization no attempt will be made to include any of the record in this report.

National Safety Code—The states of Oregon, Utah and Idaho have all adopted the National Safety Code as a standard to govern overhead line construction. It would be of considerable advantage from the standpoint of uniformity if Washington were to also adopt the National Code. For this reason members from the Engineering Section have held several conferences with state officials with this end in view.

Residence Metering—In the past, the 5-amp. meter was used for residences without electric ranges. On account of the increased use of electrical household equipment, many of the 5-amp. meters were subjected to heavy overloads. As a result it became quite common practice to abandon the 5-amp. meter and standardize on the 10-amp. for residence use. Recently a new 5-amp. meter was developed to withstand the same overload as the old 10-amp. meter and still maintain equal accuracy on high loads and much better accuracy on low loads. This caused most companies again to make use of the 5-amp. meter. In the past most companies have used a 15-amp. meter for range services. A new 10-amp. meter has been developed which is the equal of the old 15-amp. and may be used now in its place.

Accident Prevention—The accident prevention committee under the leadership of J. B. Fisken has been making a strenuous effort to bring before company executives the greater importance of better organized and more vigorous work in connection with accident prevention work. The humanitarian side of the question alone should be sufficient to enlist its hearty support, but even if we forget this side of the issue, authentic figures in Mr. Fisken's possession emphasize the financial saving to the company and individual where accident prevention work is earnestly prosecuted in accordance with modern proved practices.

All committees in the Engineering Section have very conscientiously labored on the problems tending toward the advancement and betterment of the light and power industry by solving for themselves many of the local problems and applying such information as is adaptable, emanating from the study and research of the Engineering National Section. The value of the engineering work is being more and more felt as the intricacy of operation increases.

Electrical Apparatus Committee[2]

The activities of this committee during the past year have been restricted to studying two problems, one on the subject of lightning arresters and the other on metal tank mercury rectifiers.

The subject of lightning arrester practice in the Northwest is of special interest to power system operators, first because of the rather mild lightning conditions and second, because of the heavy costs involved in complete protection. Most of the companies, therefore, have followed a somewhat modified program, supplying full protection at the large or more important stations and limited or no protection at small and less important stations.

A very interesting and instructive paper was presented by R. McKay on this subject at the general meeting of the Engineering Section held in Spokane March 8-9, 1928.

The second subject, that of metal tank mercury rectifiers, was presented at the March meeting by John Bankus. Such rectifiers have been in use on railway service in Europe for several years past and are gradually gaining favor in the United States. A number of installations have been made in this country, one of which is in Portland, consisting of two 750-kw. units serving an interurban railway at 1,400 volts.

This paper deals with the development, theory of operation, characteristics and efficiency of the rectifier. The following quotation from the paper on the subject of efficiency is of special interest. "The losses in a rectifier set include the usual transformer losses, the losses in the rectifier itself, and the power required for the auxiliary equipment. The loss in the rectifier itself is equal to the cathode current times the voltage drop in the rectifier arc. The total arc drop is made up of three parts. The values given by Mr. Marti include a drop of 6.3 volts at the anode surface, a drop of 5.7 volts at the cathode surface, and a drop in the arc which varies between 0.1 and 0.4 volts per centimeter of arc length. The combined ionization drop in a commercial rectifier is equal to approximately 20 volts and is practically independent of the rectifier load as well as the normal voltage for which the unit is designed. The latter feature accounts for the very high efficiencies of the rectifiers when operating at high voltages."

The members of the apparatus committee are to be complimented for their help in furnishing data to Mr. McKay and Mr. Bankus for use in the preparation of their interesting and instructive papers.

[2] **D. W. Proebstel**, Portland Electric Power Company, chairman. **Grays Harbor Railway & Light Company**: W. S. Hill. **Idaho Power Company**: E. A. Woodhead. **Mountain States Power Company**: G. McClellan. **Northwestern Electric Company**: Frank Lewis. **Pacific Power & Light Company**: C. S. Knowles, D. R. McClung. **Portland Electric Power Company**: John Bankus. **Puget Sound Power & Light Company**: Joseph Hellenthal. **Utah Power & Light Company**: D. L. Brundige. **The Washington Water Power Company**: R. McKay.

Underground Systems Committee[2]

Six subjects were studied by this committee during the year. These subjects were then offered as topics for discussion at the Engineering Section meeting held in Spokane, March 8 and 9, 1928.

[2] **E. F. Pearson**, Northwestern Electric Company, chairman. **Idaho Power Company**: T. A. Purton. **Northwestern Electric Company**: S. B. Clark. **Portland Electric Power Company**: J. M. Gillham. **Puget Sound Power & Light Company**: C. H. Hoge. **Utah Power & Light Company**: P. P. Ashworth. **The Washington Water Power Company**: F. L. Rohrbach.

F. L. Rohrbach, The Washington Water Power Company, sponsored the subject entitled, "Use of Duplex or Concentric Cables for Edison Feeders and Mains, and Single or Multi-Conductor Cable for a.c. or d.c. Service." Mr. Rohrbach presented this topic in the shape of an economic study. Carrying capacity characteristics and detailed costs of the various types of cables were furnished.

C. H. Hoge, Puget Sound Power & Light Company, sponsored the topic entitled, "Migration of Cable Compound." Mr. Hoge presented some actual cases of cable compound migration and offered recommendations for minimizing migration troubles.

J. M. Gillham, Portland Electric Power Company, sponsored the subject entitled, "Underground Cable Accessories." Mr. Gillham brought out the fact that improvements have been made by manufacturers in some accessories such as junction boxes, oil fuses, cutouts, but that there still exists considerable room for improvement in design. Mr. Gillham makes a recommendation that in order to reduce outages, all accessories should have a liberal safety factor and overload should be avoided.

S. B. Clark, Northwestern Electric Company, sponsored the subject entitled, "The Ohm Bug in Open Air Terminals." He was assisted by Professor F. O. McMillan and students of Oregon State Agricultural College. Mr. Clark pointed out the fact that air spaces in terminals are starting places for internal flashover and puncture. He offered a new design of terminal to protect against the occurrence of air spaces by migration of compound.

J. S. Volpe, Portland Electric Power Company, sponsored the topic entitled, "Locating Faults on Transmission and Distributing Cables." Mr. Volpe discussed the limitations of each method of testing cables for faults and concluded with recommendation that there should always be on hand voltage and equipment necessary for fault reduction as a last resort. From his study it is apparent there is still room for improved methods of cable testing.

E. F. Pearson, Northwestern Electric Company, sponsored the subject entitled, "Oil Saturated Wood Pulp Paper vs. Oil Saturated Manila Paper for Cable Insulation on Intermediate Voltages." Statistics are quoted to show that the mechanical strength of wood pulp paper is almost as great as Manila paper and dielectric strength of wood pulp is higher. The recommendation is made that oil saturated wood pulp paper be used for insulation of cable and be given preference for all voltages above 600.

This committee wishes to report that the topic system as tried out for the first time at the Spokane meeting was a decided success. Instead of presenting papers, each member was permitted to present a topic within a period of time not exceeding two minutes. A maximum of five minutes per person was allowed for discussion of each topic. It was found that six topics could be easily handled in an hour and a half and that a considerable amount of valuable discussion on all papers was obtained.

The above are all the Engineering Section committee reports filed in time for publication in this issue. Reports of the other committees will be incorporated in the 1928 Convention Proceedings.

Public Relations Section Reports

Co-operation with Educational Institutions Committee[2]

The activity of the committee during the current association year has been confined largely to assisting the National Committee on Co-operation wth Educational Institutions in its nation-wide survey. The objectives of this survey, as stated by Carl D. Jackson, chairman of the national committee, are as follows:

1. To ascertain to what extent the study of public utilities is given consideration in college and university courses.
2. To determine the character and extent of the demand of the public utility industry for college trained personnel.
3. To discover the opportunities offered by the industry for such trained personnel.
4. To ascertain the extent to which the industry is willing and able to co-operate with the colleges and universities in the training of such personnel.

The conduct of this survey was undertaken by the questionnaire method, and a set of questions, so framed that the answers thereto would reflect conditions in the industry with respect to the points stated above, was prepared by the national committtee to be sent out by the geographic divisions to their member companies. To explain the survey and to pave the way for a prompt and widespread response, the national committee sent Prof. C. O. Ruggles, formerly dean of the School of Business Administration, Ohio State University, and a member of the national committee, to visit the geographic divisions and hold meetings with division committees and representatives of educational institutions in their territories.

[2] **R. M. Boykin,** Puget Sound Power & Light Company, chairman. **The California Oregon Power Company:** H. L. Bromley. **Eastern Oregon Light & Power Company:** J. P. Lottridge. **Pacific Power & Light Company:** S. E. Skelley. **Portland Electric Power Company:** W. P. Strandborg. **Utah Power & Light Company:** Colonel E. LeRoy Bourne. **The Washington Water Power Company:** W. H. Ude.

Professor Ruggles' visit to the Northwest was made the occasion for two meetings, one in Seattle, Feb. 24, and one in Corvallis, Ore., Feb. 28, 1928. To these meetings, beside the divisional committee and other representatives of the utility company members, were invited also the deans, associate professors and instructors in departments of engineering, business administration, commerce, economics and law in the leading state and private universities and colleges of Idaho, Washington and Oregon. A summary of the attendance at the two meetings combined is as follows:

Representatives from Utility Companies	19
University of Washington	8
Washington State College	1
Oregon State Agricultural College	23
Reed College	1
Willamette University	1
	53

The 34 representatives from the educational institutions came from the following departments:

Engineering	9
Business Administration, Commerce, Economics, Etc.	19
Law	1
C.R.E.A.	1
Unidentified as to Department	4
	34

At these meetings Professor Ruggles discussed the reasons for the survey, outlined its scope, explained the questions to be asked, and left instructions for the issuance of the questionnaires by the division secretary. The questionnaires were subsequently sent out to the chief executives of 34 member companies, omitting those smaller companies that are subsidiaries of the larger ones, and at the date of filing this report for publication a number of replies have been received.

Customer Ownership Committee[2]

This committee has held two meeting during the present year; one at Portland, Ore., on Jan. 26, and one at Seattle, Wash., on April 23. These meetings have been well attended and considerable thought has been given to the subject of customer ownership.

[2] **Dwight Ware,** Puget Sound Power & Light Securities Company, chairman. **The California Oregon Power Company:** D. G. Tyree. **Idaho Power Company:** L. W. Brainard. **Mountain States Power Company:** Sumner C. Palmer, Jr. **Pacific Power & Light Company:** S. E. Skelley. **Portland Electric Power Company:** E. G. Jarvis. **Puget Sound Power & Light Company:** N. W. Brockett. **Utah Power & Light Company:** Geo. B. Thomas. **The Washington Water Power Company:** W. H. Ude.

Customer Ownership Still Important

It is the consensus of opinion of the committee that the customer ownership idea is still of vital importance to the welfare and public relations of the public utilities. The customer ownership idea has been car-

ried on at one time or another for the past six or seven years by the larger member companies of the Northwest association and these companies report that it has come up to every expectation and they are enthusiastic regarding its continuance.

While it is difficult to estimate accurately the benefits to the companies from a public relations standpoint, it is the opinion of those connected with the public relations departments of these companies that it has been a decided help as well as being the medium of enlightening the public as to the policies and principles upon which these companies are founded. With this enlightenment and a greater degree of co-operation from the public, there is every reason to believe that it will be of increasing value in the future.

Danger of Losing Customer Owners

The customer ownership idea has gone through two stages. First, it has been successfully sold to the executives of the companies as an excellent medium to improve public relations, as well as to secure new capital to carry on the expansion of the business. Second, it has been successfully sold to the public as a whole, who have responded in ever increasing numbers as subscribers to the stock, with the result that each year has shown an increased amount of capital secured as well as an increasing number of local stockholders. The third stage to which it is now coming is the problem of keeping the number of stockholders from decreasing. In general, the original offering of stock through the customer ownership plan was at rates of from 7 per cent to 7½ per cent, and with the lowering of rates the natural increase in market value of these shares of stock has taken place, with the result that many of the customer stockholders are tempted to sell their holdings to take a profit, which results in losing them as stockholders.

The success of the public utilities in selling to large numbers of local people is common knowledge to a great many investment bankers, with the result that many of these stockholders are called upon with the idea of trading them out of their stock in the local company. The committee suggested no plan to minimize the decrease of stockholders from these two causes, but it is believed that a great deal of good work that has been done during the last four or five years will be undone unless some study, as well as effort, is made to make it attractive for local stockholders to continue to hold their stock.

Companies Should Arouse Stockholders' Interest

It is the general opinion of the committee that the companies have taken considerable for granted, believing that by securing a large amount of new capital, and a consequent number of new stockholders, that they have accomplished all the purposes of the customer ownership idea. The committee, with this in mind, believes that the companies are not taking advantage of the many opportunities of bringing the companies closer to the stockholders, either by letter, pamphlet, or through personal contact with its officials, and suggests that throught be given to improving this situation. It is also believed that many of the communications to stockholders are so legal in form, as well as being void of any personal touch, as to be hardly understandable to the average layman. While the committee understands that in some cases this is necessary, it believes, and recommends, that many of these communications can be humanized and given a more personal touch so that they will be more interesting and understandable.

From time to time employees of these great organizations, either in groups or as individuals, do heroic work or perform duties in times of disaster that are of untold importance to the welfare and life of many thousands of people. The efficiency and timeliness of their work, we believe, should be brought to the attention of the stockholders, who in reality are their employers, and who, we feel, would be interested.

The committee also feels that other opportunities are being overlooked by not bringing more forcefully to the stockholder the fact that he is a part owner of the company, and believes that this particular phase of his relationship can be developed to a higher degree. However, care should be taken so that the stockholder should not be led to feel that he is being taken advantage of personally or used.

Women's Committee[2]

The primary aim of the Women's Committee is to educate utility women in the principles of the industry and through this education enable them to advance public information and establish good will and confidence between the companies and the public they serve.

With this purpose in mind the Women's Committee of the Northwest division has followed closely during the past year the program outlined by the National Women's Committee. The major subjects for study were: electricity in the home, economics of utilities and public contact.

Under the subject, "Electricity in the Home," the women studied rewiring and refixturing, electrical housekeeping, home service and safety, special consideration being given to educating home-makers in the complete electrification of their homes rather than in the possession of just a certain number of appliances.

The most important subject under "Economics of Utilities," was that of government in business. The subject of rates was also stressed.

Customer contact placed emphasis upon the importance of the proper attitude of utility employes toward the public and upon close co-operation with women's clubs and schools.

The first meeting of the association year was held in Spokane, Oct. 17, 1927. Marguerite Butler, member-at-large, National Women's Committee, made a report of the meeting of the committee at Chicago, Aug. 22 and 23, 1927, bringing to the Northwest committee an interesting outline of the national program for 1927-1928.

It was the decision of the committee at this meeting to hold an essay contest during the year as suggested by George L. Myers, chairman, Public Relations Section. The chairmen were also requested to interest the women of their companies in the essay contests being sponsored by the different committees of the section, particular attention being called to the importance of participation in the public speaking contest.

The subcommittees formed last year to study personnel problems, closer co-operation with women's clubs and programs for smaller companies, were requested to continue their work. The personnel of these committees was carried forward with as little change as possible in order that there might be no interruption in their programs.

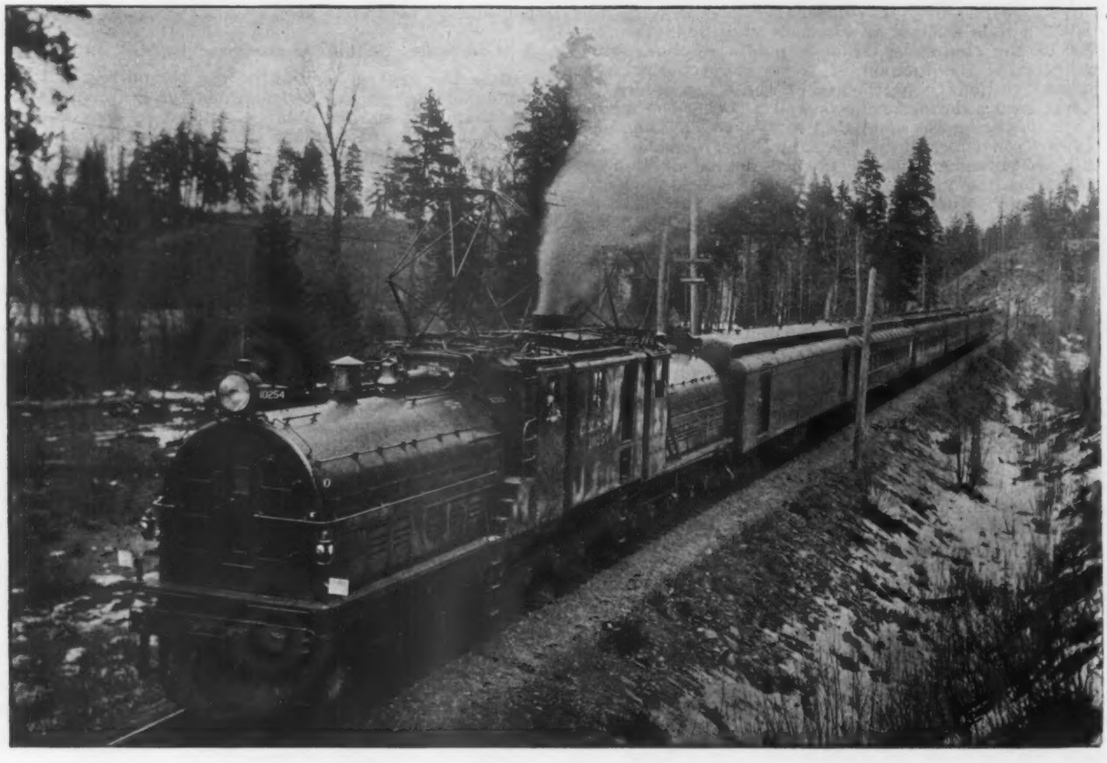
It was advised that instruction on the subject of government in business be given by company executives or under their direction. In order that the committee might inform itself on the Boulder Dam project an analysis of the Swing-Johnson Bill by Paul S. Clapp, managing director, N.E.L.A., was distributed.

Reports of educational meetings and other activities of the local committees since the Boise meeting in February of the past association year were made by each company chairman and round table discussion followed each report.

Reports of Subcommittees

The mid-year meeting of the committee was held in Seattle, Feb. 27, 1928. At this meeting Stella Dorgan, Northwest representative, reported for the home service subcommittee. Miss Dorgan has been compiling a list of companies in this division having home service departments and those not operating such departments. The home service departments of these companies work with homemakers teaching them new and better uses of the service offered by utility companies. They are important factors in increasing the sale of utility products and a very desirable method of improving public relations. Miss Dorgan has also been furnishing write-ups of all home service activities in our division to the

[2] **Mary K. Walsh,** The Washington Water Power Company, chairman. **The California Oregon Power Company:** Mrs. Helen Minkler. **Deschutes Power & Light Company:** Minnie C. Johnson. Eastern **Oregon Light & Power Company:** Anna Gyllenberg. **General Electric Company:** Martha O. Goldapp. **Grays Harbor Railway & Light Company:** Esther Miller. **Idaho Power Company:** Mrs. Gertrude McDevitt. **Mountain States Power Company:** Stella Dorgan. **Northwestern Electric Company:** Mrs. A. W. Angell. **Pacific Power & Light Company:** Thelma Kelly. **Portland Electric Power Company:** Marguerite Butler. **Puget Sound Power & Light Company:** Mrs. Nell Laws. **Utah Power & Light Company:** Mrs. A. E. Moyle.



national committee for publication in the new home service bulletin, "Twice-Told Tales."

The subcommittee on closer co-operation with women's clubs has been in close touch with women's organizations. Since the personnel of the Northwest committee hold memberships in from one to five or six clubs the work of this subcommittee has been of considerable value.

The subcommittee on programs for smaller companies found little difficulty in exchanging ideas for a variety of programs because of the amount of educational material being distributed by the N.E.L.A.

The sucommittee on personnel problems has been in touch with universities and colleges in Washington, Oregon and Idaho, in an endeavor to ascertain if these colleges provided an extension course in personnel work which would be available to the chairmen. This group advocated a further education of the personnel of the women's committees in the different companies in good telephone practice and recommended attention to the study of a booklet on this subject.

Company Committee Activities

The reports of the various chairmen indicated splendid progress in each company covering educational meetings, all companies having held monthly meetings.

The programs for these educational meetings consisted of talks on the industry by executives, or papers and talks prepared by the women themselves. There was a tendency this year among most of the companies to have a larger number of women employees take an active part in each program, interesting current electrical events being assigned as subjects to a group of women for reading or for papers to be read at each meeting. In a number of instances outstanding men and women in the communities, whose message would be of particular educational value, were invited to talk to the committee. Among the subjects covered at these meetings were: electrical appliances, safety and accident prevention, lighting, re-fixturing, re-wiring, rates, customer-ownership, Boulder Dam and analysis of Swing-Johnson Bill, political vs. private ownership and courtesy in business. Question boxes containing questions concerning the local company and its policies were used with success. Playlets on utility subjects and educational films have also had a place on the programs.

Tme committee has also carried on a large number of other activities. Two companies have held debates on the subject, "Resolved, That Public Opinion Is Influenced by Contact With the Average Employee to a Greater Extent Than by Executives." Another company has conducted an essay contest on the subject, "If We Had No Electricity." Two districts of one company committee held electric appliance exhibits to which the club women of the community were invited. Another served waffles and coffee during a waffle iron campaign and followed this with demonstrations which paralleled other appliance campaigns. These exhibits resulted in a number of appliance sales and prospects.

Two committees edited their company house organs, receiving much favorable publicity in newspapers and among club women of their community, and another edited the first house organ ever printed by the company.

All committees are taking an active part in the women's clubs in their communities, in a number of instances taking entire charge of club programs, and helping to secure engagements for utility speakers. They have also presented utility playlets and loaned the talent of their committees for club programs.

Feeling that the health and contentment of the women employees is a vital factor in their efficiency the chairmen have organized swimming and gymnasium classes and provided health talks for their girls. In this manner they have promoted the positive idea of health among the girls which is of considerable value to their companies.

Public speaking classes and sewing, cooking and art classes have also been organized. One committee has a very active dramatic club and has presented several plays before the employees. A number of committees have taken entire charge of company dances, budgeting the expense and appointing all committees.

During the Christmas season many of the companies provided Christmas baskets for needy families and one company made scrap books for the crippled children confined to the local Shrine hospital. In a number of instances this was the first time the companies had undertaken such philanthropic work.

At the time of this report the attention of the committee is centered upon the essay contest which does not close until April 30. It promises to be most successful and will represent very tangible evidence of a year of intensive study by the personnel of the women's committee in the respective companies.

Growth and Progress of Committee

At the close of the association year in July, 1927, there were twelve active committees in the Northwest division. We are closing this year with thirteen active committees. Twelve of these commttees are formed in utility companies and one is made up of supply companies. With slightly more than three years of organization the women's committee of the Northwest division shows gratifying progress. The accomplishments of the past year are attributed by the chairman to the hard work, self-sacrifice and devotion to the principle of the committee manifested by the women who formed its personnel.

I ask the executives and other utility representatives to continue to give every possible encouragement to the women's committee. It is willing, anxious and eager to help in the promotion of better public relations.

General Committee Reports

Educational Committee[2]

The report of the national educational committee for the year ending Feb. 29, 1928, shows a total enrollment in all N.E.L.A. courses from the Northwest Geographic Division of 28. In point of actual numbers as well as on the basis of the number per capita, this is the smallest of all divisions.

Data on only 21 of these enrollments are available in this office at the present time. The division of these into the number of enrollments from the various companies and in the various courses offered is as follows:

Northwestern Electric Co.	17	Practical Electricity	1
Utah Power & Light Co.	1	Lighting Sales	11
Puget Sound P. & L. Co.	1	Power Sales	7
Grangeville E. L. & P. Co.	1	Elementary Accounting	1
Idaho Power Co.	1	Advanced Accounting	1
	21		21

It is interesting to note that of the 28 enrollments recorded in the division for the year ending February, 1928, 20 were enrolled in the last month of the report year, and that in the first month of the current report year, March, 1928, there were 26 enrollments from six member companies divided fairly evenly among the six courses offered. This would seem to assure a better record for the division in the current year than was recorded in the year just closed.

In partial explanation of the apparent recent stimulus to enrollment, it may be said that the committee was not fully organized until late in 1927 and was not active until early in 1928. At that time an article descriptive of the courses offered was prepared for publication in the company house organs, and in some cases the company's representative on the committee used other means to bring the courses to the attention of those in his organization that might be interested, and to encourage enrollment.

The committee conceives its principal function as being to spread as widely as possible among the rank and file of the personnel of the member companies information about the courses offered, and, with this purpose in view, quotes hereinbelow the descriptive article used by some of the companies' house organs as referred to above. A complete descriptive circular of any course will be sent to any inquirer by the chair-

[2] Berkeley Snow, Electrical West, chairman. Idaho Power Company: E. C. Kiersted. Mountain States Power Company: John N. Adams. Northwestern Electric Company: R. W. Faville. Pacific Power & Light Company: Geo. T. Bragg. Portland Electric Power Company. Geo. Sullivan. Puget Sound Power & Light Company: Col. H. G. Winsor. Utah Power & Light Company: M. L. Cummings, Jr. The Washington Water Power Company: W. H. Ude.

man or by the enquirer's company's representative on the committee. Companies not now represented on the committee may secure such representation by writing to the chairman nominating a representative.

For Company Magazines Outlining Educational Course Offered by the N.E.L.A.

It may not be generally known among the employees of the ..... Company that the National Electric Light Association offers at a nominal price a number of educational courses available to all utility company employees. These courses are designed for employees specializing in the departments indicated below, and are intended to help the employee taking them to a more thorough understanding of his chosen work through supplementing his practical knowledge of his subject by a systematic study of the principles on which it is based and of successful practices developed from past experience. These courses, with their costs, are as follows:

Elementary Accounting Course	$16
Advanced Accounting Course	40
Course in Practical Electricity	12
Lighting Sales Course	12
Merchandise Sales Course	12
Power Sales Course	12

A short outline of each of these follows:

Elementary Course in Bookkeeping and Accounting—This course is designed to give the student a proper understanding of the fundamentals on which is based the accounting theory and practice of all business. It is divided into seven lessons, after finishing which the student will be enabled to grasp the more extensive accounting system necessary in connection with the electric utility business.

Advanced Course in Electrical Utility Accounting—This course was established in response to a very evident demand for standard instruction in accounting for the electrical industry. To get the best results from it, the student should have a thorough fundamental training in bookkeeping, and those desiring to take this course should give satisfactory evidence of having received instruction equivalent to the elementary course offered by the association. There are 36 lessons covering the entire practice followed in the accounting methods of utility companies.

Course in Practical Electricity—This course has been specially prepared for central station men not having a technical education. It is written in plain English without higher mathematics and without unnecessary technical expressions. It takes up in ten lessons the theory of electricity, beginning with magnetism, and continuing on through a discussion of d.c. circuits, generators and motors, to the fundamental principles of a.c. generation, transformation, distribution, and utilization.

While it might appear that the course was intended particularly for the engineering, operating and meter department men, it is true that it has much to offer the commercial department men, since it explains the principles back of the subjects these men daily discuss with customers and prospects.

Commercial Courses—The three commercial courses—**Lighting Sales, Merchandise Sales, Power Sales**—are divided into two parts—the first part of five lessons being common to all three. This part discusses salesmanship, public relations, elements of electricity, principles of rates, and wiring for light and power. The second part varies as is indicated by the titles, so that the salesman in any of the three branches of the business may take only that course applicable to the specialized knowledge demanded in his work.

The **Lighting Sales Course** takes up principles of illumination, and residence, commercial, industrial and outdoor lighting, in seven lessons.

The **Merchandise Sales Course** discusses advertising, merchandising, heating and household appliances, industrial applications and selling campaigns, in five lessons.

The **Power Sales Course** studies motors and their applications, steam, oil and gas engines, isolated plants and industrial heating, in five lessons.

All of these courses are conducted by the correspondence method and generally speaking lessons are forwarded monthly or semi-monthly as desired. Some of them are adapted to study by group meetings or classes where each lesson may be discussed as it is received, but this method is in no sense necessary to the average student's successful completion of any of the courses. Further information about any of these courses can be secured from

.....

(Fill in name of company member of committee.)